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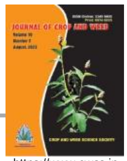

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Impact of sowing environment and thermal regime on performance of Indian mustard (*Brassica juncea* L.) in Red Laterite Zone of West Bengal

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ABSTRACT

The field trial was carried out to investigate the effect of transplanting dates on different heat indices and productivity of Indian mustard (Brassica juncea L.). Three Indian mustard cultivars viz., NRCHB 101, Kesari Gold, and Kesari 5111) were transplanted from November to December viz., 3rd November, 14th November, 25th November and 6th December. The field data pointed out that the number of days needed to reach various phenological phases reduced with late in transplanting. Maximum growth, productivity as well as the highest value of heat summation indices like GDD, HTU, PTI and HUE at various phenological stages were recorded with Kesari Gold cultivar and the mustard crop transplanted on 3rd November. SPAD index of Kesari Gold variety was significantly greater than of remaining varieties. Mustard cultivar Kesari Gold cultivar recoded highest yield (1107 Kg ha^{-1}) whereas the 3rd November transplanted mustard recorded maximum seed yield (1361 Kg ha^{-1}).

Keywords: GDD, HTU, PTI, HUE, seed yield, transplanted mustard

Rapeseed-mustard is one of the major edible oilseed crops which ranked after soybean, and palm in the earth. Mustard is a tropical as well as sub-tropical crop which requires cool temperature and dry weather with bright sunshine. In India, after groundnut, mustard is the most prominent crop under oilseeds, which contributes 28.6% of the oilseed production and 27.8% of the oilseed economy of the country (Shekhawat *et al*., 2012). Meteorological elements play foremost role in achieving the optimum plant growth, development, and productivity because weather dynamically impacts the physical assertion of genetic potential of the crop (Khavse *et al*., 2014). Among the weather elements, temperature is more crucial to determine the time of sowing and subsequently the various phenophase durations and crop yield (Tewari and Singh, 1993). The optimum time of planting is one of the prominent non-monetary agronomic inputs (Mondal and Islam, 1993; Mondal *et al*., 1999) for successful mustard cultivation. Temperature impact on different phenophase, and productivity of crops can be observed in field situations through growing degree-days (GDD) (Chakravarty and Sastry 1983; Bishnoi *et al*.,1995; Akhter *et al*., 2015). As mustard is a photo-thermosensitive crop optimum meteorological conditions require to attend various phenological stages which also states the relationship of various heat summation indices with phenological stages. GDD, HTU, PTI and HUE are used to assess the crop phenology at different stages (Gouri *et al*., 2005). Transplanting of mustard helps to overcome the yield reduction by adjusting the delayed sowing of mustard after harvesting of the previous *kharif* crop. Therefore, the current experiment was assumed to study the impact of transplanting date and cultivar on heat summation indices-phenological stages, growth and performance of Indian mustard under mild and short winter condition in lateritic belt of West Bengal.

MATERIALS AND METHODS

The trial was conducted at Agricultural Farm, Palli-Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, (20°39′N latitude, and 87°42′E longitude with an mean altitude of 58.9 meters above mean sea level) in sub-humid tropical zone during the winter season of 2020-21 (Fig. 1).

The soil was sandy loam, slightly acidic pH (6.01), low in available N (137.5 kg ha^{-1}) and P (12.1 kg ha^{-1}) and intermediate in available K (163.5 kg ha^{-1}). Total rainfall received during cropping period from 19th October to 9th March, 2021 was 8.4 mm. Weather parameters are presented in Fig. 2 and 3.

The treatment comprises of three cultivars i.e., NRCHB 101, Kesari Gold, and Kesari 5111 with four transplanting dates i.e., 3rd November, 14th November, 25th November, and 6th December. The experiment was carried through factorial RBD design having three replications. PVC pipe materials were used to make the micro-pots, where the seedlings were raised. A mixture

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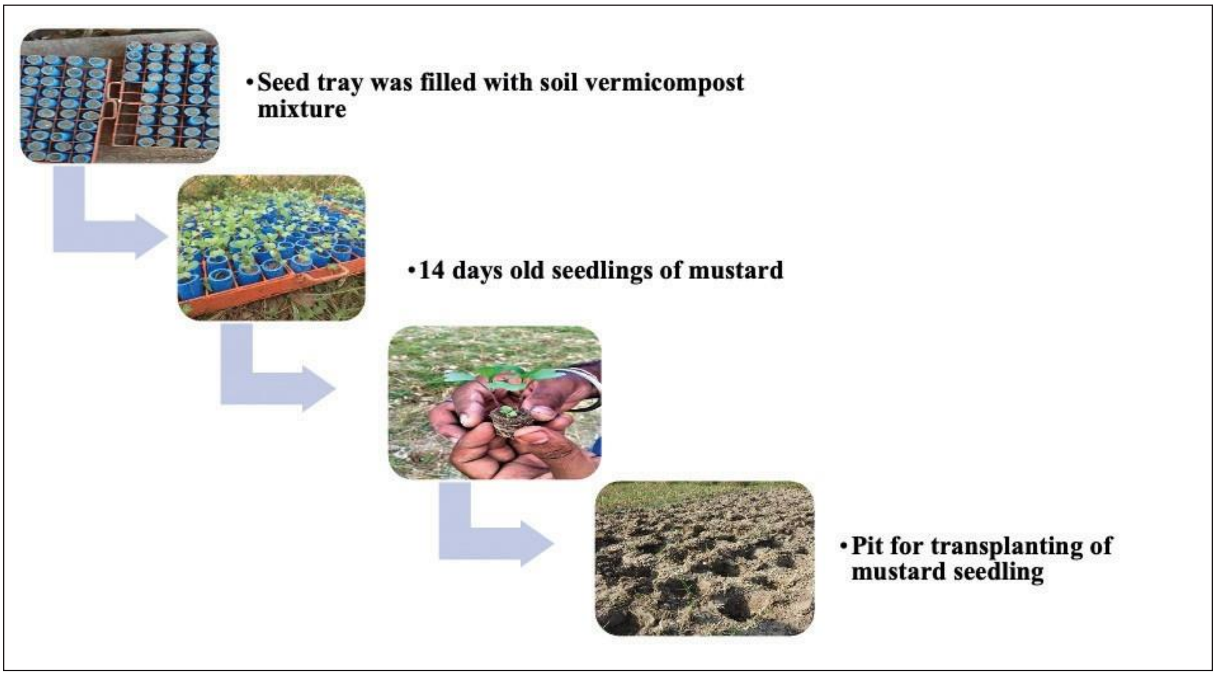
of soil and vermicompost with a ratio of 2:1 was used to make the micro-potting materials to fill the pots. In each pot, 1-2 seeds were sown and then a vermicompost layer was given to cover the seeds. Until the seed germination started, micro-pots were watered two times a day (morning and evening) regularly. Frequent sprinkling of water was also provided after seedling emergence. In the pots, raising of seedlings were done for fourteen days. Step by step seedling making and establishment in main field:



The dimension of each plot was 4.5 m × 4.5 m and planting geometry was 45 cm x 45 cm. A fertilizer dose of 120 Kg N, 60 Kg P_2O_5, and 60 Kg K_2O ha^{-1} was used in the transplanted mustard crop. The full dose of P_2O_5 and 45 Kg of K_2O and 60 Kg of N were applied in the holes (made by hole-making implement) as basal, during the time of transplanting. The 30 Kg of N was firstly top dressed at 40 DAT, and rest 30 Kg of N and K_2O were top dressed secondly at 60 DAT. Randomly five plants were selected from every single plot at 75 DAT for estimating CGR and SPAD. The heat summation indices like GDD, HTU, PTI and HUE were calculated from the maximum and minimum temperature data after calculating the required days to attend all the phenological stages. The weather-elements data were obtained from the IMD centre of Sriniketan. The siliqua length, test weight and secondary including tertiary branches were recorded at harvesting and after threshing the seed yield and harvesting index were recorded. SPAD meter (MC-100, Apogee instrument) was used to measure the SPAD value from the 3rd leaf of the plants at the different growth stages. The following equations were used-

i) Crop growth rate (CGR) calculated by using this method:

$$\text{Crop growth rate} = \frac{W_2 - W_1}{t_2 - t_1} \ (\text{g m}^{-2}\text{day}^{-1})$$

Where, W_2 and W_1 were the final and initial dry weights of all plant parts per unit land area at times t_2 and t_1, respectively.

ii) The growing degree days or heat units were calculated by using base temperature of 5.0^{0}C for mustard:

$$\text{GDD (°C days)} = [(T_{max}+T_{min})/2]\text{-Tb}$$

Where, $T_{max..}$ = maximum temperature (°C), T_{min}= minimum temperature (°C) and T_b = base or threshold temperature.

iii) The product of GDD and corresponding actual sunshine hours for that day was computed on daily basis as:

HTU (°C days hours) = GDD× actual sunshine hours

iv) Pheno-thermal index (PTI) was calculated by this formula:

PTI (^{0}C days day^{-1}) = GDD ÷ Growth days

v) Heat use efficiency calculated using this formula:

$$\text{HUE (Kg ha}^{-1}\text{°C days}^{-1}) = \frac{\text{Accumulated biomass } (\text{Kg ha}^{-1})}{\text{Accumulated heat units } (^{\circ}\text{C day})}$$

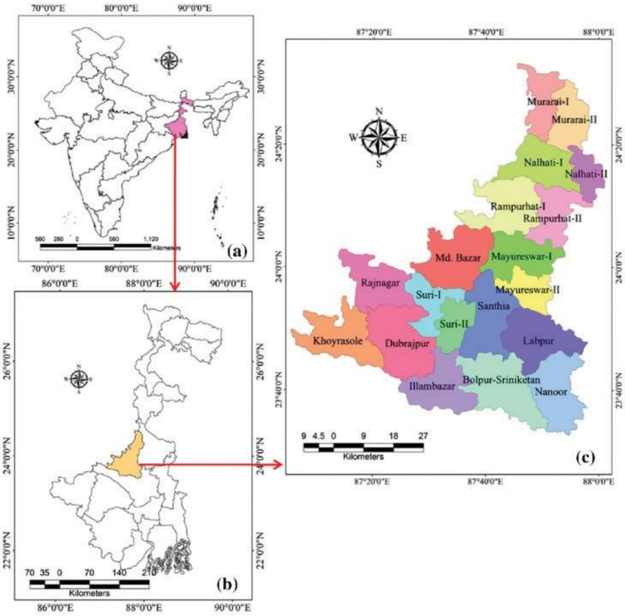


Fig. 1:The experimental area: map of India-pointing up West Bengal; West Bengal map-pointing up Birbhum the experimental location

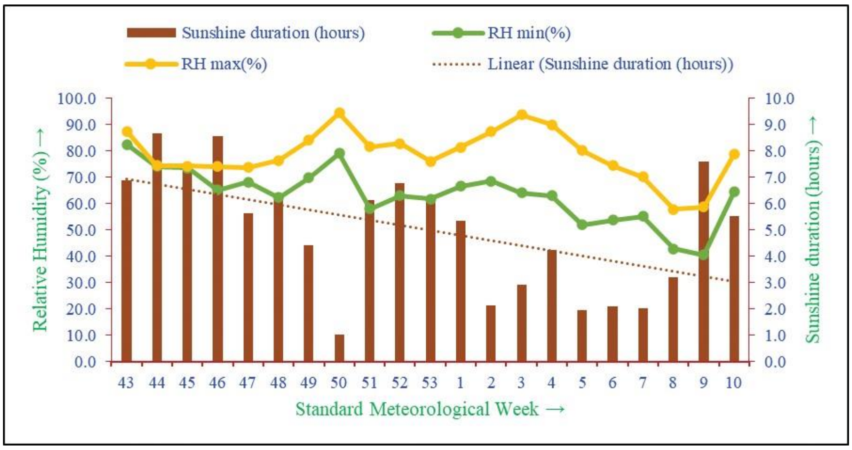


Fig. 2 : Relative humidity and sunshine duration during crop season

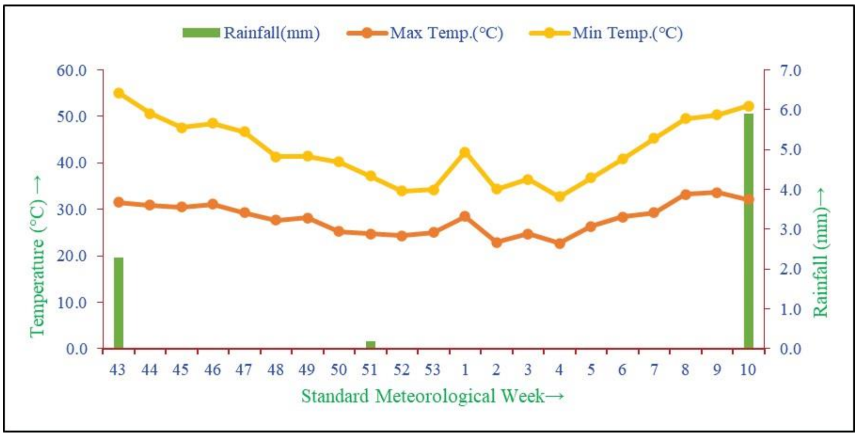


Fig. 3 : Temperature and rainfall during crop season

RESULTS AND DISCUSSION

Crop growth rate (CGR)

The result showed that cultivar Kesari Gold recorded highest CGR of 5.40 g m^{-2} day^{-1} over Kesari 5111 with 4.32 g m^{-2} day^{-1} and was at par with NRHB 101 of 5.33 g m^{-2} day^{-1}(Table 1). This might be due to the superior genetic expression which resulted maximum growth. Mustard crop transplanted on 3rd November recorded highest value of crop growth rate of 7.63 g m^{-2} day^{-1}as compared to the three delayed planting. This might be due to longer crop period and optimum meteorological circumstances. These findings are in agreement with the results of Muhal *et al.* (2014) and Kumar *et al.* (2018).

Table 1: Effects of cultivar and transplanting date on CGR and SPAD value of mustard crop

Treatments	CGR (g m^{-2} day^{-1}) (50-75 DAT)	SPAD value (75 DAT)
Cultivar		
NRCHB 101	5.33	22.49
Kesari Gold	5.40	23.42
Kesari 5111	4.32	20.99
SEm (±)	**0.25**	**0.33**
LSD (p=0.05)	**0.85**	**1.11**
Date of transplanting		
3rd November	7.63	30.19
14th November	6.10	18.30
25th November	4.24	26.20
6th December	2.09	14.50
SEm (±)	**0.25**	**0.33**
LSD (p=0.05)	**0.73**	**0.96**

SPAD value

SPAD value of the mustard crop at 75 DAT, was significantly affected by different cultivars and transplanting dates (Table 1). The greater genetic potential led Kesari Gold cultivar recorded higher SPAD value of 23.42 over Kesari 5111 (20.99) and was at par with NRCHB 101 (22.49). Mustard crop transplanted on 3rd November recorded highest SPAD value of 30.19 over other transplanting dates due to the early crop establishment which provided the proper agrometeorological conditions for higher leaf area and chlorophyll content. Similar findings reported by Dhillon *et al.* (2021) in rice.

Phenological stages

Duration required to attend the phenological stages of mustard crop was influenced by cultivar and transplanting dates (Table 2). The NRCHB 101 cultivar recorded higher duration to attend emergence (5.67 days), flower initiation (37.25 days), 50% flowering (44.25 days) and siliqua initiation (51.83 days) over Kesari Gold and Kesari 5111. It might be due to the diverse genetic make up of the cultivars. The days taken from emergence to siliqua development of all tested cultivars decreased with late in transplanting (Gupta *et al.*, 2017).

The mustard crop transplanted on 3rd November recorded higher duration to attend emergence (5.00 days), flower initiation (39.33 days) 50% flowering (47.00 days) and siliqua initiation (53.89 days) over other three transplanting dates. This might be due to congenial temperature of soil and air during this transplanting period. Late transplanting mustard crop took minimum number of days to attain all the phenological-stages. It might be due to greater temperature after the period of flower-initiation, which required to fulfil the GDD and thermal units of crop for reaching various phenological-stages. Alike outcomes were described by Adak *et al.* (2011), Kaur *et al.* (2018) and Bhardwaj *et al.* (2020) that crop sown earlier reached to attain physiological stages later over delayed dates of sowing.

Agrometeorological indices

Growing degree days (GDD)

The GDD necessity of mustard crop to achieve various phenophase varied with cultivars and date of transplanting (Table 3).NRCHB 101 cultivar accumulated higher GDD at emergence (113.9 °C days), flower initiation (645.8 °C days), 50% flowering (742.8 °C days) and siliqua initiation (845.9 °C days) over Kesari Gold and Kesari 5111 due to genetic potential. The crop transplanted on 3rd November accumulated highest GDD to attain emergence (113.7 °C days), flower initiation (760.5 °C days), 50% flowering (882.6 °C days) and siliqua initiation (990.7 °C days) over late transplanted of mustard crop. It might be due to shorter crop duration for late transplanted mustard. Ahatsham *et al.* (2018), Bhardwaj *et al.* (2020) and Prasad *et al.* (2020) were reported similar kind of outcomes.

Helio-thermal units

The helio-thermal units (°C days hour) of mustard crop significantly influenced by different cultivars and transplanting dates at all four phenological phages (Table 4). The accumulated helio-thermal units of mustard cultivar NRCHB 101 (814.7, 3930.6, 4397.7 and 4858.5 °C days hour) was highest over Kesari Gold and Kesari 5111 at all four phenological stages. These variations resulted due to long duration of the NRCHB 101 cultivar and different genetic expression. The mustard crop transplanted on 14th November availed higher value of

Table 2: Effect of cultivars and transplanting date on duration required to attend phenological stages of mustard

Treatments	Days required			
	Emergence of seedlings (Days)	**Flower initiation (Days)**	**50% flowering (Days)**	**Siliqua initiation (Days)**
Cultivar				
NRCHB 101	5.67	37.25	44.25	51.83
Kesari Gold	3.98	35.50	42.75	50.75
Kesari 5111	4.73	35.75	42.75	50.83
SEm (±)	**0.10**	**0.48**	**0.45**	**0.31**
LSD (p=0.05)	**0.31**	**1.41**	**1.33**	**0.92**
Date of transplanting				
3rd November	5.00	39.33	47.00	53.89
14th November	4.96	37.67	44.33	51.33
25th November	4.92	35.33	42.33	51.67
6th December	4.29	32.33	39.33	47.67
SEm (±)	**0.09**	**0.42**	**0.39**	**0.27**
LSD (p=0.05)	**0.26**	**1.22**	**1.15**	**0.79**

Table 3: Effect of cultivars and transplanting date on GDD in different phenological stages

Treatments	GDD (°C days)			
	Emergence stage	**Flower initiation stage**	**50% flowering stage**	**Siliqua initiation stage**
Cultivar				
NRCHB 101	113.9	645.8	742.8	845.9
Kesari Gold	78.74	618.3	721.3	829.0
Kesari 5111	94.34	622.3	721.3	829.0
SEm (±)	**0.67**	**2.96**	**6.89**	**3.91**
LSD (p=0.05)	**1.97**	**8.68**	**20.21**	**11.48**
Date of transplanting				
3rd November	113.7	760.5	882.6	990.7
14th November	104.6	682.0	785.9	891.8
25th November	97.53	591.6	680.4	788.7
6th December	66.77	481.2	564.9	667.2
SEm (±)	**0.58**	**2.56**	**5.97**	**3.39**
LSD (p=0.05)	**1.71**	**7.51**	**17.50**	**9.94**

accumulated HTU (840.4 °C days hour) at emergence. The mustard crop transplanted on 3rd November recorded higher accumulated HTU at flower initiation (5547.5 °C days hour), 50% flowering (6186.1 °C days hour), and siliqua initiation stage (6361.1 °C days hour °C days hour), whereas, delay in transplanted HTU consumption deceased. Longer duration of the mustard might be the cause for these results. Similar findings were observed by Kingra and Kaur (2012); Singh *et al.* (2014); Prasad *et al.* (2020).

Pheno-thermal index

Results exhibited no significant difference in pheno-thermal index (PTI) among the tested cultivars at various phenophase of mustard (Table 5). The early transplanted mustard crop on 3rd November recorded highest PTI value (22.78, 19.34, 18.78 and 18.35°C days day^{-1}) over delayed transplanting. It might be due to reduction in accumulated GDD value with delayed transplanting. Identical results reported by Singh *et al.* (2014), Singh *et al.* (2019) and Prasad *et al.* (2020).

Table 4: Effect of cultivar and transplanting date on HTU (°C days hour) in different phenological stages

Treatments	HTU (°C days hour)			
	Emergence stage	**Flower initiation stage**	**50% flowering stage**	**Siliqua initiation stage**
Cultivar				
NRCHB 101	814.7	3930.6	4397.7	4858.5
Kesari Gold	609.9	3826.1	4327.1	4805.5
Kesari 5111	692.9	3838.5	4327.1	4805.5
SEm (±)	**4.85**	**26.16**	**19.53**	**17.47**
LSD (p=0.05)	**14.23**	**76.73**	**57.26**	**51.24**
Date of transplanting				
3rd November	770.5	5547.5	6186.1	6361.1
14th November	840.4	4743.4	4923.5	5286.0
25th November	826.1	3068.4	3600.0	4356.7
6th December	386.1	2100.8	2693.0	3289.0
SEm (±)	**4.20**	**22.66**	**16.91**	**15.13**
LSD (p=0.05)	**12.32**	**66.45**	**49.59**	**44.38**

Table 5: Effect of cultivar and transplanting date on pheno-thermal index in different phenological stages and heat use efficiency at harvesting stage

	Emergence stage	**Flower initiation stage**	**50% flowering stage**	**Siliqua initiation stage**	**Harvesting stage**
	PTI (°C days day^{-1})				**HUE (Kg ha^{-1} °C days^{-1})**
Cultivar					
NRCHB 101	19.63	17.20	16.67	16.26	0.49
Kesari Gold	19.68	17.32	16.77	16.37	0.63
Kesari 5111	19.64	17.30	16.77	16.35	0.47
SEm (±)	**0.27**	**0.31**	**0.16**	**NS**	**0.02**
LSD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**0.06**
Date of transplanting					
3rd November	22.78	19.34	18.78	18.35	0.75
14th November	20.89	18.13	17.73	17.40	0.54
25th November	19.52	16.74	16.07	15.36	0.49
6th December	15.41	14.88	14.36	14.20	0.35
SEm (±)	**0.23**	**0.27**	**0.14**	**0.26**	**0.02**
LSD (p=0.05)	**0.69**	**0.79**	**0.41**	**0.75**	**0.05**

Heat use efficiency

Heat use efficiency (HUE) significantly impacted by variant cultivars and transplanting dates in mustard crop (Table 5).The cultivar Kesari Gold recorded more HUE (0.63 Kg ha^{-1} °C days^{-1}) over NRCHB 101 and Kesari 5111 at harvesting stage. The discrepancy in heat summation indices can be attributed due to genetic behaviour of respective cultivars. The greater value of HUE with Kesari Gold might be due to its more seed yield (Table 5). Gupta *et al.* (2017) also observed similar results. Among dates of transplanting, HUE was found to be greater (0.75 Kg ha^{-1} °C days^{-1}) for early transplanted mustard crop (3rd November) and it reduced with delayed transplanting. This might be due to greater seed yield in earlier transplanted crop which increased thermal efficiency. Kingra and Kaur (2012); Ahatsham *et al.* (2018); Singh *et al.* (2019) and Prasad *et al.* (2020) observed identical outcomes.

Table 6: Effects of cultivars and transplanting date on yield attributes and yield

Treatments	Secondary + tertiary branches	Siliqua length (cm)	Test weight (g)	Seed yield (Kg ha^{-1})	Harvest index (%)
Cultivar					
NRCHB 101	42.87	5.06	4.01	867	29.71
KESARI GOLD	46.88	5.12	4.35	1107	33.49
KESARI 5111	39.71	4.81	3.99	819	30.96
SEm (±)	**0.77**	**0.05**	**0.08**	**34**	**1.20**
LSD (p=0.05)	**2.61**	**0.17**	**0.26**	**100**	**3.51**
Date of transplanting					
3rd November	53.61	5.35	4.62	1361	33.29
14thNovember	47.68	5.10	4.14	962	32.79
25thNovember	40.98	4.87	4.05	823	31.57
6thDecember	30.33	4.67	3.66	578	27.91
SEm (±)	**0.77**	**0.05**	**0.08**	**29**	**1.04**
LSD (p=0.05)	**2.26**	**0.15**	**0.22**	**86**	**3.04**

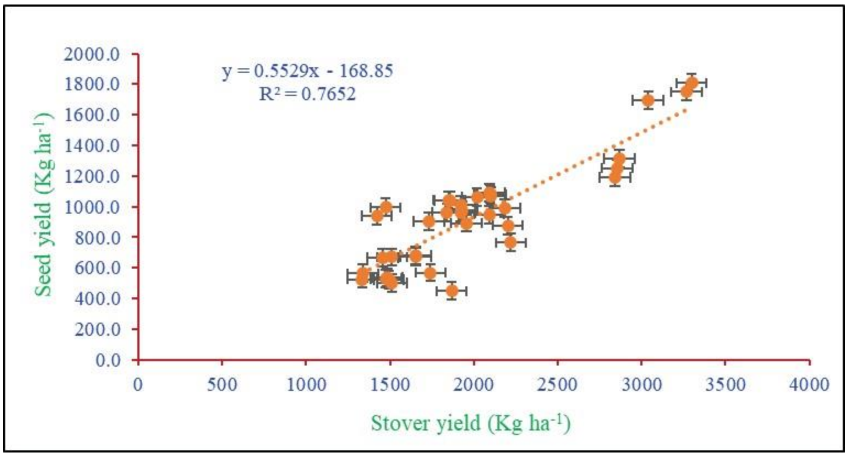


Fig. 4 : Relationship between seed yield and stover yield

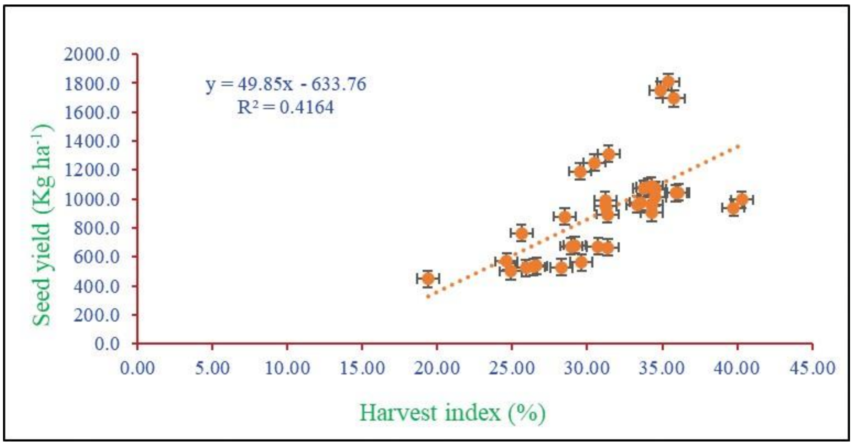


Fig. 5 : Relationship between seed yield and harvest index

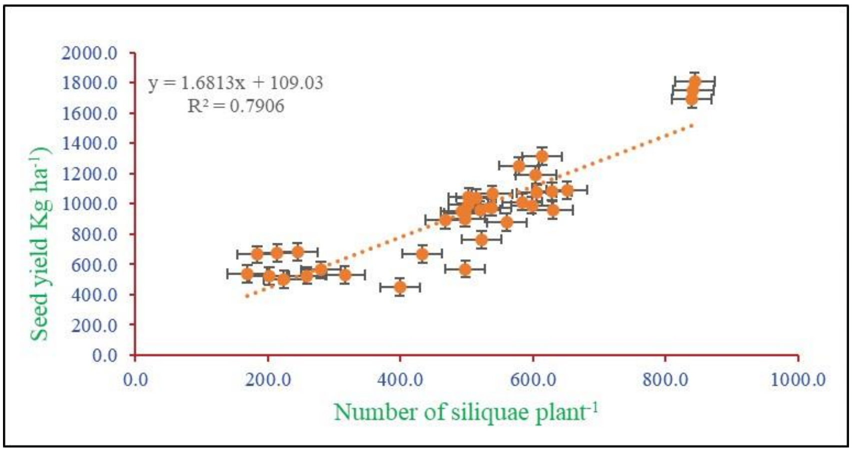


Fig. 6 : Relationship between seed yield and number of siliquae plant^{-1}

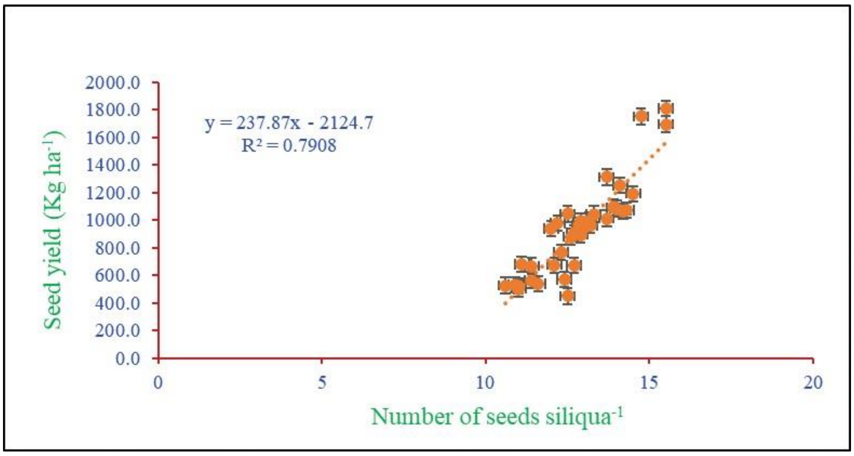


Fig. 7 : Relationship between seed yield and number of seeds siliqua^{-1}

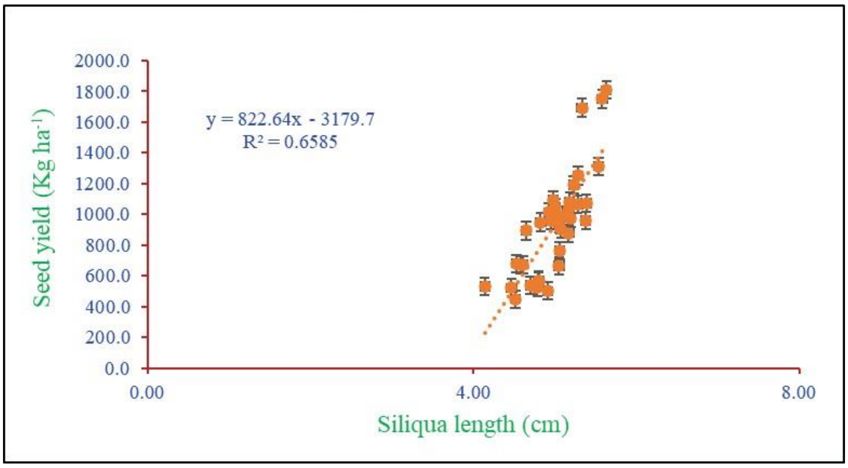


Fig. 8 : Relationship between seed yield and siliqua length

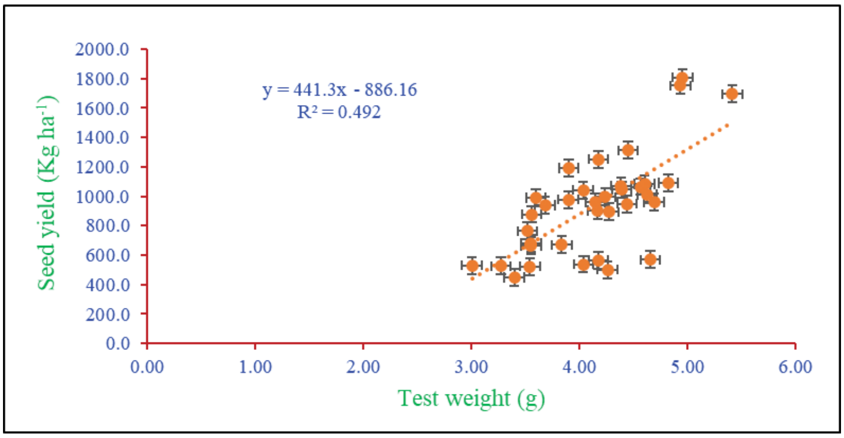


Fig. 9 : Relationship between seed yield and test weight

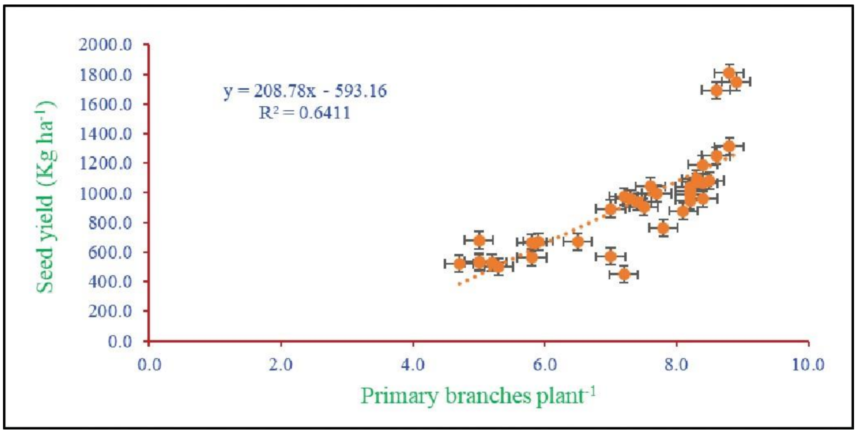


Fig. 10 : Relationship between seed yield and primary branches plant^{-1}

Number of secondary (including tertiary) branches

Maximum number of secondary (including tertiary) branches (46.88) was recorded from Kesari Gold cultivar over Kesari 5111 and NRCHB 101 (Table 6). It might be due to superior genetic potential of the cultivar that leads to higher growth attributes. The mustard crop transplanted on 3rd November exhibited significantly greater secondary (including tertiary) branches (53.61) over different transplanting dates. The reason might be that the crops sown late faced stress due to high temperature, ultimately resulted decrease in stand established and plant growth finally reduced the branches. Similar findings were observed by Bhuiyan *et al.* (2008), Bala *et al.* (2011) and Bazzaz *et al.* (2020).

Siliqua length

Results revealed that significantly higher siliqua length (5.12cm) was obtained from crop cultivar Kesari Gold over Kesari 5111 and at par with NRCHB 101, might be due to superior genetic make-up and growth characteristics (Table 6). Whereas, the mustard transplanted on 3rd November, exhibited significantly longer siliqua (5.35 cm) over delayed transplanting. This higher siliqua length of mustard crop might be due to early crop establishment, longer crop duration which led to better assimilation of photosynthates.

Test weight

The highest test weight (4.35 g) was recorded from Kesari Gold over NRCHB 101 and Kesari 5111 (Table 6). Mustard transplanted on 3rd November was revealed significantly greater test weight (4.62 g) over delayed transplanting. The decreased in test weight in delayed transplanting might be due to very short seed filling time and seeds could not develop completely in delayed planting. Akhter *et al.* (2015) also reported similar outcomes.

Seed yield

Regarding the cultivars, Kesari Gold produced significantly greater seed yield (1107 Kg ha^{-1}) over NRCHB 101 and Kesari 5111. The yield enhancement of cultivar Kesari Gold over NRCHB 101 and Kesari

5111 was 27.7 and 35.2 per cent, respectively. This might be due to better yield parameters and account of accumulation of greater thermal units, that may be due to genotypic traits of cultivar 'Kesari Gold'. Significantly maximum seed yield was exhibited when mustard crop transplanted on 3rd November yield (1361 Kg ha^{-1}). The seed yield enhancement of mustard crop transplanted on 3rd November was 41.5, 65.4 and 135.5 per cent over transplanted crop on 14th November, 25th November and 6th December, respectively. Greater seed yield of mustard crop transplanted on 3rd November may be due to accumulation of greater thermal units and crop got longer time to utilize available resources and congenial temperature. Delayed transplanted crop produced less seed yield may be due to get shorter period for less utilization resources. These findings are in agreement with the observations of Shargi *et al.* (2011); Alam *et al.* (2015) and Akhter *et al.* (2016).

Harvest index (HI)

The harvest index is a major attribute which shows the photosynthetic efficiency of plant in the direction of production of economic yield (Singh *et al*., 2018). Among the cultivar, the harvest index recorded from Kesari Gold cultivar (33.49%) which was significantly higher over NRCHB 101 and was at par with Kesari 5111. This might be due to larger seed yield and better genetic potential. The HI of crop transplanted on 3rd November was significantly greater than crop transplanted on 14th November, 25th November and 6th December transplanted crop (Table 6). The HI was significantly leesen by delayed sowing as noticed by Siadat and Hemayati (2009); Sudhir *et al.* (2013) and Gawariya *et al*. (2015).

Correlation

It was manifested that stover yield (Kg ha^{-1}), branches $plant^{-1}$, siliquae $plant^{-1}$, seeds $siliqua^{-1}$, siliqua length (cm), test weight (g) and harvest index (%) were sowing significant association with economic yield of mustard (Fig. 4, 5, 6, 7, 8, 9 and 10). The enhancement of seed yield with increasing stover yield (Kg ha^{-1}), branches $plant^{-1}$, siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$, siliqua length (cm), test weight (g) and harvest index (%) was linear. Stover yield accounted for 76.52 % variability in seed yield (Fig. 4). Similarly, harvest index accounted for 41.64 % variability (Fig. 5), number of siliquae $plant^{-1}$ accounted for 79.06% variability (Fig. 6), number of seeds $siliqua^{-1}$ accounted for 79.08% variability (Fig. 7), siliqua length accounted for 65.85 % variability (Fig. 8), test weight accounted for 49.20% variability (Fig. 9) and primary branches $plant^{-1}$ accounted for 64.11% variability in seed yield (Fig. 10). Hence, increasing stover yield (Kg ha^{-1}), harvest index (%), number of siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$, siliqua length (cm), test weight (g) and primary branches $plant^{-1}$ has direct effect for incrementing the economic yield of mustard.

CONCLUSION

From the above investigation it can be concluded that mustard cultivars transplanting in different environment along with different thermal regime has a profound influence on the growth, yield parameters and productivity in red laterite zone of West Bengal. In the changing agrometeorological conditions, Kesari Gold is most suitable among the cultivars.

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