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Effect of accumulated heat unit, heat use efficiency and solar radiation interception on mustard cultivars under different growing environment (*Brassica juncea* L.)

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Abstract
A field experiment was conducted during the *Rabi* season of 2018-19 to access the “Effect of different growing environment on growth and yield of mustard cultivars (*Brassica juncea* L.)” in silty loam soil at Agro-meteorological Research Farm of N.D. University of Agriculture & Technology, Kumarganj, Ayodhya. The experiment was conducted with RBD (Factorial) and replicated four times with nine treatment combinations consisted of three growing environment viz. 20^{th} October, 30^{th} October and 09^{th} November and three cultivars *viz.* Varuna, Narendra rai-1 (NDR-8501) and Kranti. Results revealed that 20^{th} October sown mustard crop produced significantly higher growth and yield due to fulfilment of optimum heat unit requirement, heat use efficiency and solar light interception for various processes of plant. Among the different cultivars of mustard, Varuna was recorded maximum heat unit (1660.6 ^{0}C days), heat use efficiency (0.50 g/m²/°days) and Solar radiation interception (589 MJ/m^2) from sowing to maturity produced the high yield of Indian mustard.

Keywords: Heat unit, heat use efficiency, solar radiation interception, mustard, growing environment

Introduction

Mustard (*Brassica juncea* L.) belonging to family cruciferae is the third important oilseed crop in the world after soybean (*Glycine max*) and palm oil (*Elaeis guineensis jacq*). The important mustard growing countries of the world are India, Canada, China, Pakistan, Poland, Bangladesh and Swedan. India is one of the important country among the oilseeds producing countries of the world. Mustard is the second most important edible oil seed crop after groundnut in India. India occupies the second position in area after China and third position in production in the world after China and Canada. Indian mustard is also grown where annual precipitation of 500 to 1200 mm, temperature of 6 ^{0}C to 27 ^{0}C and soil pH of 6.5 to 8.3. Mustard is the crop of tropical as well as temperate zone. The temperature requirement varies from 0.5-3.0 ^{0}C ($T_{Min.}$) to 35-40 ^{0}C ($T_{Max.}$) with an optimum temperature regime of 20-35 ^{0}C. Cool temperature, dry weather with good amount of bright sunshine increases the oil yield. Mustard needs high temperature for vegetative growth (20-32 ^{0}C) and cool temperature. If the mustard is sown late, duration is reduced due to the high temperature during the reproductive phase with concomitant reduction in yield (Kumari *et al*., 2004) [6]. The growth phase of the crop should synchronize with optimum environmental conditions for better expression of growth and yield. It is a fact that specified genotypes does not exhibit the same phenotypic characteristics in all environmental conditions. Bora (1997) [1] has reported that the yield potential of different mustard varieties may differ under different agro-climatic conditions because of their inherent capacity.

Materials and methods

An experiment was conducted at Agro-meteorological Research Farm of Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.) during Rabi season 2018-19. The farm is located 42 km away from Ayodhya city on Ayodhya - Raibareily road at 26˚47ʹ N latitude and 82˚12ʹ E longitude and at an attitude of about 113 meter above the mean sea level. The experiment was conducted in R.B.D. (Factorial).

Nine treatments combination comprised of three growing environment *viz.* crop sown on 20th October, crop sown on 30th October and crop sown on 9th November along with three cultivars *i.e.* Varuna, Nrendra-Rai-1(NDR-8501) and Kranti. The crop was fertilized with a uniform dose of nitrogen, phosphorus and potassium at 120:60:50 kg/ha, respectively. Urea, DAP and MOP were used as the source of nitrogen, phosphorus and potassium. Half dose of nitrogen along with full dose of phosphorus, potassium and sulphur were applied as basal dressing and remaining dose of nitrogen was top dressed into two equal splits. 1st split was top dressed at 30 DAS and 2nd splits dose at pre flowering stage of the crop.

Growing degree days / Heat unit

Growing degree days (GDD) at different phenological stages were calculated by using following formula:

GDD $=\sum$ heat unit (HU)

Where,

1, 2, 3… n is number of days and $i^n = 1$

$$\text{Heat unit} = \frac{T_{max.} + T_{min.}}{2} - \text{Base temp } (T_b).$$

Base temperature for mustard (*Rabi*) crop 5.0°C.

Solar radiation interception (MJ/m)

Solar radiation interception was measured at 30 days intervals and at harvest and calculated by following formula;

$$\text{LI} = \frac{\text{LI (Top of canopy) LI (Bottom of Canopy)}}{\text{LI at top of canopy}} \text{ x } 100$$

Where LI=Light interception

Heat use efficiency (g/m²/⁰cday)

Heat use efficiency (HUE) is the dry matter production per unit of heat unit by the crop. Heat efficiency (HUE) may be calculated from heat unit obtained above as following;

$$\text{HUE} = \frac{\text{Total dry matter (g/m2)}}{\text{Accumulated Heat unit (°Cdays)}}$$

Table 1: Growing degree days/Heat unit at different phenophases (˚C days) of Indian mustard as affected by growing environment and cultivars

Treatments	Phenophases					
	Emergence	Four Leaf Stage	Flower Initiation	Siliqua Initiation	Pod Development	Maturity
Growing environment						
20th Oct.	154.7	266.2	760.7	938.4	1092.9	1660.6
30th Oct.	146.0	254.6	711.9	838.7	1000.4	1520.9
09th Nov.	112.1	244.6	629.9	768.7	946.4	1423.4
Cultivars						
Varuna	137.6	255.1	700.8	848.6	1013.2	1534.9
NDR-8501	127.7	245.2	690.7	830.4	985.7	1510.2
Kranti	123.6	239.4	681.9	794.6	968.4	1410.5

Table 2: Solar radiation interception (MJ/m²) of Indian mustard as affected by different growing environment and cultivars

Treatments	Solar radiation interception/Cumulative APAR (MJ/m²)			
	30 DAS	60 DAS	90 DAS	At Harvest
Growing environment				
20th Oct.	95	271	482	589
30th Oct.	89	233	415	477
09th Nov.	91	265	477	549
Cultivars				
Varuna	90	236	429	506
NDR-8501	95	224	472	515
Kranti	89	235	436	493

Table 3: Heat use efficiency (g/m²/ºc days) of Indian mustard as affected by growing environment and cultivars

Treatments	Heat use efficiency (g/m²/ºc days)			
	30 DAS	60 DAS	90 DAS	At Harvest
Growing environment				
20th Oct.	0.10	0.18	0.49	0.38
30th Oct.	0.11	0.19	0.50	0.39
09th Nov.	0.09	0.17	0.44	0.34
Cultivars				
Varuna	0.10	0.18	0.49	0.37
NDR-8501	0.10	0.19	0.49	0.38
Kranti	0.10	0.18	0.45	0.35

Results and discussions

Meteorological parameters

Accumulated Heat Unit requirement of Indian mustard at different phenophases as affected by different growing environment and cultivars have been presented in table-1. The maximum heat Unit (GDD) requirement from sowing to maturity were recorded 1660.6 ºC days at growing environment/growing environment 20th October while minimum growing degree days/heat unit from sowing to maturity 1423.4 ºC days was observed under growing environment (09th November). Late sown mustard crop recorded minimum GDD (Heat unit) requirement at all the stages. Different cultivars had marked influence on the Heat unit/growing degree days of Indian mustard at all the phenophases. GDD ranged from 1534.9ºC days to 1410.5ºC days irrespective of different cultivars. Maximum Heat unit requirement from sowing to maturity was recorded 1534.9ºC days was obtained in Varuna cultivar, while minimum Heat unit was obtained in Kranti Cultivar 1410.5ºC days from sowing to maturity of Indian mustard. The results are corroborated with Singh *et al.* (2014) [7], Hundal *et al.* (2003) [2], and Srivastava *et al.* (2011) [9].

Solar radiation interception MJ/m² requirement of Indian mustard at different phenophases as affected by different growing environment and verities have been presented in table-2. The maximum Solar radiation interception requirement from maturity was recorded 589 MJ/m² at 20th October while minimum solar radiation interception from sowing to maturity 477 MJ/m² was observed for 30th October. Similar results are reported by Singh *et al.* (2006) [8], and Khichar *et al.* (2000) [4]. Different varieties had marked influence on the solar radiation interception (MJ/m²) of Indian mustard at all the phenophases. Solar radiation interception ranged from 493 to 515 MJ/m² irrespective of different varieties. Maximum Solar radiation interception 515 MJ/m² requirement from sowing to maturity was obtained in NDR-8501 cultivar while minimum solar radiation interception was obtained in Kranti cultivar 493 MJ/m² from sowing to maturity of Indian mustard. Similar results are reported by Keerthi *et al.* (2015) [3].

Heat use efficiency requirement of Indian mustard at different phenophases as affected by different growing environment and cultivars have been presented in table-3. The maximum heat use efficiency requirement from sowing to maturity was recorded 0.50 g/m²/ºdays at growing environment 30th October while minimum heat use efficiency from sowing to maturity 0.44 g/m²/ºdays was observed under growing environment 09th November. Late sown cultivars recorded minimum heat use efficiency requirement at all the stages. Similar results are reported by Singh *et al.* (2014) [7]. Different cultivars had marked influence on the heat use efficiency of Indian mustard at all the phenophases. Heat use efficiency ranged from 0.45 to 0.49 g/m²/ºdays irrespective of different cultivars. Maximum heat use efficiency requirement from sowing to maturity was obtained in NDR-8501 (0.49) g/m²/ºdays cultivar while minimum heat use efficiency was obtained in Kranti (0.45) g/m²/ºdays from sowing to maturity of Indian mustard. Similar results are reported by Khushu *et al.* (2001) [5], Singh *et al.* (2014) [7], Hundal *et al.* (2003) [2] and Srivastava *et al.* (2011) [9].

Conclusions

Maximum heat use efficiency requirement from sowing to maturity was obtained in NDR-8501 (0.49) g/m²/ºC days cultivar. Maximum heat unit requirement from sowing to maturity was recorded 1534.9 ºC days was obtained in Varuna cultivar. Maximum Solar radiation interception 515 MJ/m² requirement from sowing to maturity was obtained in NDR-8501 cultivar.

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