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Research Paper

Effect of different microenvironment on heat unit requirement and heat use efficiency of different lentil genotypes sown in rice fallow condition

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ABSTRACT

To utilize the rice (*Oryza sativa* L.) fallow land of the northeastern region (NER) of India and enhance the cropping intensity, a set of lentil (*Lens culinaris*) genotypes/varieties were evaluated for heat requirement and use efficiency under 2 thermal regimes in Tripura [altitude of 52 m ASL (meter above sea level)] during 2014–15 and 2015-16 (November to March). The experiment consisted of 14 lentil genotypes namely 'HUL 57', 'L 4076', 'ILL 10897', 'ILL 10893', 'BM 6', 'BM 7', 'WBL 77', 'Subrata', 'ILL-6002', 'L-1111-12', 'L-1112-18', 'L-1112-20', 'ILL-10951', and 'L 1112-07' which were sown under two thermal regimes e.g., 16th November (1st date of sowing) and 1st December (2nd date of sowing) during both the years. Results revealed that crop sown on 16th November took 3 days more than that of 1st December sowing to attain physiological maturity. 'Lentil' 'L-1112-18' took a minimum number of days (80) to reach physiological maturity stage followed by 'L-1111-12 (82 days). Crop sown on 1st December consumed more growing degree days (GDD) between different phenological stages, for example sowing to 50% emergence (113.8), 1st flower bud initiation to 50% flowering (250.4), and 50% flowering to physiological maturity (632.3) except for 50% emergence to 1st flower bud initiation (682.4) than that of 16th November sowing. Lentil variety HUL 57 required the highest GDD between all the phenological stages. Accumulated GDD and heliothermal unit (HTU) were higher for 16th Nov sowing ranged from 100.4 °C days (emergence) to 1719.5 °C days (physiological maturity) and accumulated HTU from 127.6 °C day hours (emergence) to 2199.2 °C day hours (physiological maturity) than 1st December sowing. HUL 57 accumulated the highest GDD and HTU from sowing to physiological maturity. The pheno-thermal index (PTI) was higher between sowing to 50% emergence (20.2-21.8) and 50% flowering to physiological maturity (18.2-20.1) than in between of 1st flower bud initiation to 50% flowering (16.2-17.4) and 50% emergence to 1st flower bud initiation (16.5-17.9). 'Lentil' 'HUL 57' had the highest PTI (21.3) followed by 'L-4076' (21.0) while the lowest PTI was by BM 6 (16.1) followed by 'L-1112-18 (17.1) between 50% flowering to physiological maturity. Lentil sown on 16th Nov produced more seed (1008.9 kg/ha), straw (1608.9 kg/ha), and biomass (2617.6 kg/ha) yields, and improved heat use efficiency for grain yield (0.60 kg/ha °C day^{-1}) and biomass yield (1.56 kg/ha °C day^{-1}) than that of sowing on 1st Dec. Lentil genotype BM-6 produced maximum seed yield (1270 kg/ha) followed by WBL 77 (1234 kg/ha) and L-1112-18 (1231.5 kg/ha). The highest straw yield was produced by WBL 77 (1747.5 kg/ha) followed by L-4076 (1715.5 kg/ha) and L-1112-18 (1685.5 kg/ha). However, genotype L-1112-18 produced maximum biomass yield (2917 kg/ha) followed by L-1111-12 (2894.5 kg/ha) and L-4076 (2883 kg/ha). The genotype L-1112-18 had maximum heat use efficiency for seed yield (0.90 kg/ha °C day^{-1}) and biomass yield (2.12 kg/ha °C day^{-1}). Thus, the study recommended the genotypes BM-6, WBL 77, and L-1112-18 which are heat efficient and high yielding for efficient utilization of rice fallow areas under both the thermal regimes.

Keywords: Growing degree days; Heliothermal unit, Pheno-thermal index; Physiological maturity

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In India, a significant proportion of land remains fallow [~11.7 million hectares (Mha)] after harvesting rice. India is a global leader in rice (*Oryza sativa* L.) production with ~44.6 Mha area under rice cultivation, of which about 26% area remains fallow during the *rabi* season (October - March), soon after harvest of *kharif* rice (Yadav *et al.,* 2017 and Yadav *et al.*, 2018a). Uttar Pradesh, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh West Bengal, and North Eastern states constitute most of these fallow lands (Yadav *et al.,* 2015). Such fallow lands during winter or post rainy season with diverse soil and agro-climatic conditions are potential zones for growing pulses (Yadav *et al.,* 2018a). The residual soil moisture at rice harvest may be used to raise short-season pulse crops with adequate agronomic/conservation measures (Yadav *et al.,* 2017 and Yadav *et al.,* 2018b). Cultivation of short duration and high yielding varieties of rice may vacate fields early in September-October, allowing cultivation of a succeeding pulse crop. Lentil is one such important *rabi* pulse and a prominent source of vegetable protein grown mainly on residual soil moisture (Das and Ghosh, 2012). It grows well in most rice fallow areas, however; productivity is often low due to insufficient nutrient assimilation under terminal moisture stress (Yadav *et al.,* 2018a). Hence, identifying possible strategies to overcome the terminal moisture stress in rice fallow for lentil cultivation necessitates knowledge of the site-specific and improved management practices.

The North-Eastern region of India also has a large area of rice fallow land (about 66% rice area) after the *kharif* season rice (Das *et al.,* 2016). Hence, there exists a great potential for expansion of area under pulses crops like lentil (Das *et al.,* 2014), especially in low and medium lands. However, the average seed yield of lentils in the region is very low compared with its potential yields. Many factors like lack of adequate short-duration varieties, terminal moisture and heat stress (Yadav *et al.,* 2018a), improper nutrient management (Yadav *et al.,* 2018b), and low heat efficient lentil genotypes may attribute to its low yield. Specifically focusing on the state of Tripura where the present experiment was carried out, the state has more than 60,000 ha of land that remains fallow after harvest of *kharif* rice (Yadav *et al.,* 2018a). This opens the possibilities of improving cropping intensity through the introduction of short duration and heat use efficient lentil varieties suitable for different thermal regimes, with a target to enhance farm income (Yadav *et al.,* 2018b). However, lentil genotypes suitable for different thermal regimes depending upon varying degrees of terminal heat and moisture stress are not available in the region. Considering the opportunity, to identify the suitable heat efficient lentil plant type for the different thermal regimes for sustainable resource utilization of the rice fallows and enhancing the nutritional security in the region, the attempt was made in this field experiment during *the rabi* season (the year 2014-16) to study the heat unit requirement and heat use efficiency of different lentil genotypes suitable two thermal regimes under rice fallow.

MATERIALS AND METHODS

Experimental details

A field experiment was conducted for two consecutive years during 2014–15 and 2015–16 (November to March) to identify suitable lentil varieties for cultivation under different thermal regimes after harvest of rice (rice fallow land) at the Indian Council of Agricultural Research (ICAR) Complex for North Eastern Hill Region, Tripura Centre, Lembucherra, Tripura, India. The experimental site is located at 23˚54'24.02" N and 91˚18'58.35" E at an altitude of 52 m ASL (meter above sea level). The experimental site was a sloping upland, and experience a mild and dry climate from November to March. The normal annual rainfall (average over the long term more than 30 years) at the site is 2200 mm. The experiment consisted of 14 lentil genotype/genotypes namely 'HUL-57', 'L-4076', 'ILL-10897', 'ILL-10893', 'BM-6', 'BM-7', 'WBL-77', 'Subrata', 'ILL-6002', 'L-1111-12', 'L-1112-18', 'L-1112-20', 'ILL-10951', and 'L-1112-07' those were sown under two thermal regimes e.g., 16th November (1st date of sowing) and 1st December (2nd date of sowing) during both the years. The experiment was laid out in a split-plot design in triplicate by placing the date of sowing in main plots and lentil genotypes in subplots. Lentil was sown in line at 20 cm spacing under reduced tillage condition. The subplot size was 6 m x 3 m. A recommended dose of 20 kg N, 60 kg P_2O_5, and 40 kg K_2O ha^{-1} were applied in furrows before sowing of lentil seeds and mixed properly with soil. After sowing the seed were covered with soil to give a good seed-soil contact. The crop was raised with residual soil moisture and one life-saving irrigation was provided at the flowering stage for better growth. The crop was harvested when the lentil plant matured during the 2nd fortnight of February to March. Days to the emergence and other phenological stages were recorded from each sub-plot when approximately 50 percent of the plants reached that particular stage. After physiological maturity, a net area of 4 × 2 m^2 from each sub-plot was harvested manually. Yield attributes (number of pods per plant and number of seeds per pod) and seed yield of lentil were recorded at harvest. Biomass yield was determined by taking the weight of aboveground plant parts including the grain. The seed yield of lentil was estimated from the weight of sun-dried seeds (12% moisture content) obtained from each plot after threshing and cleaning and expressed in kg/ha.

Calculation of agrometeorological indices

Climatic variables, e.g. atmospheric temperature (maximum and minimum) and bright sunshine hours, for the entire period of experiment period were obtained from the agro-met observatory situated at Cocotilla farm of the ICAR Research Complex for North Eastern Hills Region, Tripura Centre, Lembucherra, Tripura, India. The agrometeorological indices like growing degree-days (GDD), heliothermal units (HTU), phenol-thermal index (PTI), and heat-use efficiency for grain yield (HUEGn) and biological yield (HUEBio) were calculated using the following equations:

$$GDD = \frac{(MaxT+MinT)}{2} + \text{base temperature} \quad .....(1)$$

Where, MaxT = maximum daily temperature (°C), MinT= minimum daily temperature (°C)

$$HTU = GDD \times \text{bright sunshine hours (°C day hours)}$$

$$PTI = \frac{GDD\ consumed\ between\ two\ phenological\ stages}{Number\ of\ days\ taken} \quad ....(2)$$

$$HUEGn = \frac{Grain\ yield\ (kg\ ha{-}1)}{Accumulated\ GDD} \quad ......(3)$$

$$HUEBi = \frac{Biological\ yield}{Accumulated\ GDD} \quad ......(4)$$

Statistical analysis

The experimental data about each parameter of the study were subjected to statistical analysis by using the technique of analysis of variance, and their significance was tested by "F" test (Gomez and Gomez, 1984). The standard error of means (SEm±) and least significant difference (LSD) at 5% probability (P=0.05) were worked out to evaluate the differences between treatment means for each parameter studied.

RESULTS AND DISCUSSION

Attainment of phenological stages and heat units

Significant effects of sowing dates on days to 50% emergence and at the attainment of physiological maturity were observed (Table 1). However, days to initiation of the 1st flower bud and 50% flowering did not vary significantly between both the dates of sowing. Lentil sown on 16th November emerged 1 day earlier than that of 1st December sowing. In contrast to emergence, crop sown on 16th November took 3 days more than that of 1st December sowing to attain physiological maturity. Attainment of various phenological stages varied significantly among the tested lentil varieties/ genotypes. The emergence of the plant of different varieties/ genotypes took 5 to 7 days from the time of sowing. Lentil varieties/ genotypes, e.g. 'HUL 57', 'WBL 77' and 'L 1112-18' took a maximum of days (7) to emerge in the field. 'BM 7' took minimum days to attain 1st flower-bud initiation (40 days) and 50% flowering (54 days), followed by 'L 1112-18' in comparison to other varieties/ lines (Table 1). However, 'L 1112-18' needed the lowest number of days (80) to reach physiological stage, followed by 'L 1111-12' (82 days) than those by others. On the other hand, 'HUL 57' took a maximum of days to attain different phenological stages. Similar results were also reported by Yadav *et al.* (2015).

Heat units (GDDs) consumed between 2 phenological

Table 1. Effect of date of sowing and lentil genotypes on days to attain different phenological stages and growing degree-days (GDD) consumed between different phenological stages

Treatment	Days to				GDD consumed between			
	50% emergence	1st flower-bud initiation	50% flowering	Physiological maturity	Sowing and 50% emergence	50% emergence and 1st flower-bud initiation	1st flower-bud initiation and 50% flowering	50% flowering and physiological maturity
Date of sowing								
16 November	5	49	63	97	100.4	780.0	224.0	615.2
1 December	6	47	63	94	113.8	682.4	250.4	632.3
SEm±	0.2	0.5	0.5	0.6	0.5	1.5	6.0	10.8
CD (P=0.05)	0.5	NS	NS	1.8	1.3	4.2	17.1	NS
Genotypes/varieties								
'HUL 57'	7	59	74	108	130.0	875.4	262.2	718.6
'L 4076'	6	57	73	106	109.7	873.2	256.5	688.4
'ILL 10897'	5	48	63	100	90.1	746.6	227.3	737.2
'ILL 10893'	5	46	61	101	90.1	705.7	243.6	773.2
'BM 6'	6	41	55	93	109.7	609.8	232.0	692.4
'BM 7'	6	40	54	93	109.7	593.6	221.5	637.3
'WBL 77'	7	49	64	97	130.0	715.4	244.2	656.1
'Subrata'	6	50	63	96	109.7	744.9	226.3	620.1
'ILL 6002'	5	48	63	91	90.1	738.7	244.7	526.4
'L 1111-12'	6	44	58	82	109.7	655.7	232.9	416.3
'L 1112-18'	7	41	54	80	130.0	589.5	215.9	440.7
'L 1112-20'	5	42	56	84	90.1	645.2	223.1	496.4
'ILL 10951'	6	57	73	105	109.7	872.9	256.1	676.9
'L 1112-07'	5	56	70	102	90.1	869.8	234.2	652.0
SEm±	0.5	1.4	1.4	1.7	1.2	3.9	16.0	28.6
CD (P=0.05)	1.3	4.0	4.0	4.8	3.5	11.1	NS	81.1

stages (Table 1) were significantly affected by the date of sowing and varied among the lentil varieties/ genotypes. Crop sown on 1st December consumed more heat units between different phenological stages; for example sowing and 50% emergence (113.8), 1st flower-bud initiation and 50% flowering (250.4), and 50% flowering and physiological maturity (632.3) except for 50% emergence and 1st flower-bud initiation (682.4) than that of 16th November sowing. Lentil variety 'HUL 57' consumed the highest GDD between all the phenological stages (Table 1). However, varieties, viz. 'ILL 10897', 'ILL 10893', 'L 1112-20' required the minimum GDD between sowing and 50% emergence (90.1), 'L 1112-18' consumed the lowest GDD between 50% emergence and 1st flower-bud initiation (589.5) and 1st flower-bud initiation and 50% flowering (215.9) and 'L 1111-12' utilized minimum GDD between 50% flowering and physiological maturity (416.3) than that of consumed between other phenological stages by rest of the varieties/ lines (Table 1).

Accumulated growing degree-days and heliothermal unit

Accumulated GDD and HTU were significantly affected by the date of sowing and lentil genotypes (Table 2). The accumulated GDD for 16th November increased from 100.4°C day (emergence) to 1,719.5 °C days (physiological maturity) and accumulated HTU from 127.6°C day-hours (emergence) to 2199.2°C day-hours (physiological maturity), being is significantly higher than that of accumulated for 1st December sowing (Table 2).

The timely sown crop takes significantly more number of days and heat units to complete physiological maturity as compared to subsequent sowings (Gowda *et al.,* 2013; Bisht *et al.,* 2019; Kaur *et al.,* 2019). 'HUL 57' lentil accumulated the highest 'GDD' and 'HTU' from sowing to physiological maturity. This variety accumulated 130.0°C days at emergence, 1005.4 °C days at the 1st flower-bud initiation, 1267.6 °C days at 50% flowering, and 1,986.2°C days at physiological maturity. The HTU had also shown a trend similar to GDD for 'HUL 57' (Table 2). Lentil varieties, viz. 'ILL 10897', 'ILL 10893', 'L 1112-20' accumulated minimum GDD (90.1 °C days) and HTU (111.1 °C day-hours) at emergence. However, 'L 1112-18' could attain different phenological stages with an accumulation of GDD 719.5°C day for the 1st flower-bud initiation, 935.4 90.1 °C days for 50% flowering and 1,376.1 90.1 °C day for physiological maturity, and HTU 906.8 °C day-hours for the 1st flower-bud initiation 1,183.2 °C day-hours for 50% flowering and 1,756.3 °C day-hours for physiological maturity (Table 2).

Table 2. Effect of date of sowing and lentil genotypes on accumulated growing degree-days (GDD) and heliothermal units (HTU) at different phenological stages

Treatment	GDD (°C day)				HTU (°C day hours)			
	50% emergence	1st flower-bud initiation	50% flowering	Physiological maturity	50% emergence	1st flower-bud initiation	50% flowering	Physiological maturity
Date of sowing								
16 November	100.4	880.4	1,104.4	1,719.5	127.6	1,117.7	1,404.9	2,199.2
1 December	113.8	796.1	1,046.5	1,678.7	141.4	997.7	1,326.0	2,147.0
SEm±	0.5	1.5	5.4	8.7	0.4	3.0	4.4	5.3
CD (P=0.05)	1.3	4.3	15.3	24.8	1.2	8.5	12.5	15.1
Genotypes/Varieties								
'HUL 57'	130.0	1005.4	1,267.6	1,986.2	165.4	1,272.2	1,616.7	2,529.9
'L 4076'	109.7	982.9	1,239.5	1,927.8	138.6	1,240.8	1,581.1	2,455.7
'ILL 10897'	90.1	836.7	1,064.0	1,801.2	111.1	1,057.3	1,349.8	2,292.7
'ILL 10893'	90.1	795.8	1,039.5	1,812.7	111.1	1,002.7	1,317.1	2,306.2
'BM 6'	109.7	719.5	951.5	1,643.8	138.6	906.8	1,203.7	2,096.2
'BM 7'	109.7	703.4	924.8	1,562.2	138.6	888.8	1,168.6	2,098.5
'WBL 77'	130.0	845.5	1,089.6	1,745.7	165.4	1,068.9	1,382.2	2,223.9
'Subrata'	109.7	854.7	1,080.9	1,701.0	138.6	1,079.2	1,371.9	2,165.3
'ILL 6002'	90.1	828.8	1,073.4	1,599.9	111.1	1,045.9	1,361.8	2,040.6
'L 1111-12'	109.7	765.4	998.3	1,414.6	138.6	965.3	1,263.2	1,807.1
'L 1112-18'	130.0	719.5	935.4	1,376.1	165.4	906.8	1,183.2	1,756.3
'L 1112-20'	90.1	735.3	958.4	1,454.8	111.1	926.4	1,213.9	1,860.7
'ILL 10951'	109.7	982.7	1,238.8	1,915.7	138.6	1,238.2	1,582.0	2,439.7
'L 1112-07'	90.1	959.9	1,194.0	1,846.1	111.1	1,208.5	1,521.2	2,350.7
SEm±	1.2	4.0	14.2	23.1	1.1	7.9	11.6	14.1
CD (P=0.05)	3.5	11.3	40.4	65.5	3.2	22.5	33.0	40.0

Pheno-thermal index

The pheno-thermal index (PTI) for consecutive phenological stages was also computed and is presented in Table 3. The PTI between 50% emergence and 1st flower-bud initiation and between 50% flowering and physiological maturity significantly affected by the date of sowing; however, between sowing and 50% emergence and between 1st flower-bud initiation and 50% flowering did not vary significantly between both dates of sowing. In general, PTI was higher between sowing and 50% emergence (20.2–21.8) and between 50% flowering and physiological maturity (18.2–20.1) than between of 1st flower-bud initiation 50% flowering (16.2–17.4) and 50% emergence and 1st flower bud initiation (16.5–17.9). Several other researchers also reported that, PTI is affected by the growing season environment (Hari Ram *et al.,* 2012; Gill *et al.,* 2014; Dar *et al.,* 2018; Bist *et al.,* 2019). The PTI varied significantly only between 50% flowering and physiological maturity among the different lentil genotypes. However, PTI did not vary significantly between sowing and 50% emergence, 50% emergence and 1st flower-bud initiation, and between 1st flower-bud initiation and 50% flowering among the different lentil genotypes (Table 3). Lentil plant type 'HUL 57' had the highest PTI (21.3) and followed by 'L 4076' (21.0), while the lowest PTI by 'BM 6' (16.1) followed by 'L 1112-18' (17.1) between 50% flowering and physiological maturity.

Yield and heat-use efficiency

Yield and heat-use efficiency were significantly affected by the different thermal regimes and lentil types (Table 4). Lentil sown on 16th November gave more seed (1008.9 kg/ha), straw (1,608.9 kg/ha), and biomass (2,617.6 kg/ha) yields, and improved heat-use efficiency for grain yield (0.60 kg/ha °C/day) and biomass yield (1.56 kg/ha °C/day) than that sown on 1 December. The greater seed and biomass yield might be attributed to the accumulation of more heat units when the crop was sown on 16th November than that sown on 1 December. The higher yield under 16th November sowing might have contributed to higher heat-use efficiency than 1st December sowing (Hari Ram *et al.,* 2012; Gill *et al.,* 2014; Dar *et al.,* 2018; Bisht *et al.,* 2019). Lentil 'BM 6' showed the maximum seed yield (1,270 kg/ha), being statistically at par with lentil 'WBL 77' (1,234 kg/ha) and 'L 1112-18' (1,231.5 kg/ha) and significantly higher than those produced by other lentil genotypes (415 to 1,214 kg/ha). The highest straw yield was given by 'WBL 77' (1,747.5 kg/ha), this was at par with straw yield produced by 'L 4076' and 'L 1112-18' than those produced by others (1,358.5 to 1,680.5 kg/ha). However, genotype 'L 1112-18' produced the maximum biomass yield (2,917 kg/ha) which was statistically at par with 'L 1111-12' (2,894.5 kg/ha) and 'L 4076' (2,883 kg/ha) and significantly higher than that produced by other lentil genotypes (1,806.5 to 2,862.5 kg/ha). Variation in seed, straw, and biomass yields

Table 3. Effect of date of sowing and lentil genotypes on phenothermal index (PTI)

Treatment	Sowing to 50% emergence	50% emergence to 1st flower-bud initiation	1st flower-bud initiation to 50% flowering	50% flowering to physiological maturity
Date of sowing				
16 November	21.8	17.9	16.2	18.2
1 December	20.2	16.5	17.4	20.1
SEm±	0.6	0.3	0.5	0.4
CD (P=0.05)	NS	0.7	NS	1.2
Genotypes/Varieties				
'HUL 57'	20.9	16.9	16.8	21.3
'L 4076'	20.6	17.1	17.1	21.0
'ILL 10897'	20.9	17.3	15.8	19.7
'ILL 10893'	20.8	17.3	15.6	19.6
'BM 6'	21.6	17.5	16.1	18.3
'BM 7'	20.5	17.5	16.0	16.1
'WBL 77'	21.5	17.1	16.4	19.9
'Subrata'	20.4	17.0	17.1	19.1
'ILL 6002'	20.7	17.2	16.7	18.6
'L 1111-12'	21.4	17.4	16.1	17.5
'L 1112-18'	21.1	17.6	16.6	17.1
'L 1112-20'	20.9	17.5	17.0	17.8
'ILL 10951'	21.2	17.0	19.4	21.2
'L 1112-07'	21.8	17.1	18.3	20.4
SEm±	1.7	0.7	1.3	1.1
CD (P=0.05)	NS	NS	NS	3.2

Table 4. Effect of date of sowing and lentil genotypes on yield and heat use efficiency (HUE)

Treatment	Seed yield (kg/ha)	Straw yield (kg/ha)	Biomass yield (kg/ha)	HUE of grain yield (kg/ha °C/day)	HUE of biomass yield (kg/ha °C/day)
Date of sowing					
16 November	1,008.7	1,608.9	2,617.6	0.60	1.56
1 December	893.2	1,541.4	2,434.6	0.55	1.48
SEm±	6.7	16.7	15.7	0.01	0.02
CD (P=0.05)	18.9	47.3	44.6	0.01	0.04
Genotypes/varieties					
'HUL 57'	627.5	1,418.0	2,045.5	0.32	1.03
'L 4076'	1,167.5	1,715.5	2,883.0	0.61	1.50
'ILL 10897'	415.0	1,391.5	1,806.5	0.23	1.00
'ILL 10893'	802.5	1,525.0	2,327.5	0.44	1.28
'BM 6'	1,270.0	1,592.5	2,862.5	0.77	1.74
'BM 7'	1,055.0	1,598.5	2,653.5	0.68	1.71
'WBL 77'	1,234.0	1,747.5	2,981.5	0.71	1.71
'Subrata'	1,135.0	1,600.5	2,735.5	0.67	1.61
'ILL 6002'	1,094.0	1,639.0	2,733.0	0.68	1.71
'L 1111-12'	1,214.0	1,680.5	2,894.5	0.86	2.04
'L 1112-18'	1,231.5	1,685.5	2,917.0	0.90	2.12
'L 1112-20'	675.0	1,358.5	2,033.5	0.46	1.39
'ILL 10951'	757.5	1,593.5	2,351.0	0.39	1.23
'L 1112-07'	635.0	1,506.0	2.141.0	0.35	1.16
SEm±	17.6	44.1	41.7	0.01	0.04
CD (P=0.05)	50.0	125.0	118.1	0.04	0.11

of lentil among the plant type maybe because of its inherent genetic potential and duration (Yadav *et al.,* 2015). Lentil 'L 1112-18' had higher HUE for yield (0.90 kg/ha °C/day) and biomass yield (2.12 kg/ha °C/day) than the rest of lentil genotypes except 'L 1111-12' (Table 4). The higher seed and biomass yields might be contributed to higher heat-use efficiency in these lentil genotypes.

Thus, accumulated GDD and HTU were higher in case of 16th November sowing, ranging from 100.4°C days (emergence) to 1,719.5°C days (physiological maturity) and accumulated HTU from 127.6°C day-hours (emergence) to 2,199.2 °C day-hours (physiological maturity) than 1 December sowing. 'HUL 57' lentil accumulated the highest GDD and HTU from sowing to physiological maturity. Lentil sown on 16 November produced the maximum seed and straw yields, and improved the HUE for grain yield and biomass yield. Lentil genotype 'BM 6' produced the maximum seed yield (1,270 kg/ha), followed by lentil 'WBL 77' (1,234 kg/ha) and 'L 1112-18' (1,231.5 kg/ha). Lentil 'L 1112-18' exhibited the maximum heat-use efficiency for seed and biomass yield. Thus, the study indicated that lentil genotype 'BM 6', 'WBL 77' and 'L 1112-18' are heat-efficient and high-yielding for efficient utilization of rice-fallow areas under both the thermal regimes.

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