https://doi.org/10.29321/MAJ.10.A01332

Madras Agric. J. 92 (7-9) : 392-397 July-September 2005

Heat Unit Requirement for Horsegram (*Macrotyloma uniflorum L.*) cultivars as influenced by spacing and nitrogen

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Abstract : A field experiment was conducted to determine the effect of spacing and nitrogen on heat unit requirement, growth and yield of horsegram (*Macrotyloma uniflorum L.*). Regarding the crop phenology, observation indicated that the crop had maturity period ranging from 95 to 100 days and 98 to 106 days for CO_1 and $Paiyur_1$ respectively. Analysis of phenophase wise heat units showed the highest value at late reproductive phase (pod initiation to pod maturity) followed by vegetative phase (emergence to branching) in both the cultivars. It has been observed that application of nitrogen @ 10 kg ha^{-1} had advanced the days to flower initiation by 4 days in CO_1 and 3.5 days in $Paiyur_1$. The treatment with nitrogen @ 10 kg ha^{-1} and spacing 30 x 10 cm recorded the greater values of crop growth characters. However, the treatment with nitrogen @ 10 kg ha^{-1} and spacing 30 x 5 cm recorded the greater values of yield characters in both the cultivars.

Key words : Horsegram, Photo Thermal Unit, Helio Thermal Unit, Phenology.

Introduction

Horsegram (*Macrotyloma uniflorum L.*) is native to India and now, it is cultivated in many parts of the world (Bogdan, 1977). It can be used as pulse, fodder and cover crops. It occupies an area of 0.09 m ha with a production of 0.04 m tones in Tamil Nadu (Anon, 2002). Due to its low yield potential of 459 kg ha^{-1} the seeds are usually broadcasted during the late rainy season, with out any fertilizer application. Being a low priced leguminous and drought resistant crop, it is necessary to improve its productivity by adopting improved agronomic management practices.

Temperature regime during growth period is known to influence the phenological development of plants. The heat unit (temperature index) requirement varies according to growth stages and thus the occurrence of a phenological event can be predicted based on thermal indices like Growing Degree Days (GDD) and Photo Thermal Unit (PTU) (Iwata, 1979).

Generally, temperature and photoperiod affects the crop phenology up to flowering. Bhatia *et al.* (1997) reported that initiation of flowering and the start of pod development stages were the most susceptible to variation in photoperiod. Crop phenology can be used to specify the most appropriate date and time of specific development process. The duration of each phenophase determines the accumulation and partitioning of dry matter in different organs (Dalton, 1967). Wang (1960) reported that the duration of particular stage of growth was directly related to temperature and thus the duration of crops can be approximated using daily air temperature data. Meaningful application of agro-climatic data and calculated indices provide a scientific basis for determining the effect of temperature and photoperiod on phenological behaviour of any crop. Although these techniques are yet to be studied in India on a regional scale, a few studies have been conducted as local experimentation (Sastry and Chakravarty, 1982) for many field crops and no studies are available for

Table 1. Accumulated Growing Degree Days (AGDD), Accumulated Photo thermal units (APTU) and Accumulated Heliothermal units (AHTU) required to attain various phenophases of Horsegram

Phenophase	Variety : CO_1					Variety : $Paiyur_1$				
	N_0S_0	N_0S_1	$N_{10}S_0$	$N_{10}S_1$	Mean	N_0S_0	N_0S_1	$N_{10}S_0$	$N_{10}S_1$	Mean
AGDD										
P1	222.5	222.5	222.5	222.5	222.5	208.8	208.8	208.8	208.8	208.8
P2	327.7	298.9	298.9	285.1	302.7	285.5	312.6	285.5	298.8	295.6
P3	245.4	233.5	174.3	188.1	210.3	301.2	300.1	260.6	247.3	277.3
P4	75.8	116.4	85.6	112.8	97.7	121.1	126.8	99.9	116.4	116.1
P5	132.8	132.8	180.6	167.6	153.5	119.1	105.3	149.3	132.8	126.6
P6	522.1	487.7	475.7	515.7	500.3	597.4	472.6	505.2	487.7	515.7
P7	1526.3	1491.8	1437.6	1491.8	1486.9	1633.1	1526.2	1509.3	1491.8	1540.1
APTU										
P1	2571.9	2571.9	2571.9	2571.9	2571.9	2414.4	2414.4	2414.4	2414.4	2414.4
P2	3768	3437.4	3437.4	3278.1	3480.2	3283.3	3594.9	3283.3	3435.6	3399.3
P3	2844.7	2703.8	2017.1	2176.3	2435.5	3487.0	3476.3	3015.4	2863.0	3210.4
P4	878.7	1350.2	992.4	1307.9	1132.3	1404.8	1470.9	1158.8	1350.2	1346.2
P5	1539.9	1539.9	2094.4	1944.2	1779.6	1385.0	1227.9	1731.3	1539.9	1471.0
P6	6161.2	5751.3	5601.9	6076.1	5897.6	7073.5	5580.1	5958.4	5751.3	6090.8
P7	17764.4	17354.5	16715.1	17354.5	17297	19048.0	17764.5	17561.6	17354.4	17932.0
AHTU										
P1	1644.7	1644.7	1644.7	1644.7	1644.7	1577.6	1577.6	1577.6	1577.6	1577.6
P2	2245.0	2021.7	2021.7	1916.1	2051.1	1864.8	2088.8	1864.8	1983.2	1950.4
P3	1793.8	1640.5	1240.8	1346.4	1505.4	2241.1	2278.4	1864.5	1746.2	2032.6
P4	646.8	1023.3	666.2	904.1	810.1	1069.0	1108.4	876.5	1023.3	1019.3
P5	1239.5	1239.5	1620.2	1528.2	1406.8	1104.7	804.0	1386.3	1239.5	1133.6
P6	4605.9	4243.8	4140.5	4474.1	4366.1	5432.9	4318.5	4425.1	4243.8	4605.1
P7	12175.6	11813.5	11334.0	11813.5	11784.2	13290.1	12175.6	11994.8	11813.5	12318.5

P1 Sowing to emergence
P2 Emergence to branching
P3 Branching to flower initiation
P4 Flower initiation to 50% flowering
P5 50% floweering to pod initiation
P6 pod initiation to pod maturity
P7 Sowing to pod maturity

Table 2. Effect of spacing and Nitrogen application in Horsegram CO_1 and $Paiyur_1$

Treatments	Plant height (cm)		No. of branches / Plant		No. of pods / Plant		No. of pods / m^2		Days to 50% flowering		Grain Yield (kg/ha)	
	CO_1	$Paiyur_1$	CO_1	$Paiyur_1$	CO_1	$Paiyur_1$	CO_1	$Paiyur_1$	CO_1	$Paiyur_1$	CO_1	$Paiyur_1$
N_0S_0	120.7	119.6	9.4	8.9	19.9	21.8	1333.3	1460.6	60.8	64.3	418.8	460.0
N_0S_1	119.5	123.6	9.6	8.7	19.5	22.5	643.5	742.5	60.8	66.0	420.0	470.0
$N_{10}S_0$	138.1	129.4	10.6	9.4	21.7	24.5	1453.9	1641.5	55.3	60.3	638.5	641.0
$N_{10}S_1$	138.4	139.4	10.6	10.8	27.8	26.9	917.4	887.7	57.0	61.3	563.5	562.5
SEd	4.10	3.96	0.43	0.60	2.38	1.51	163.6	192.9	1.00	1.52	47.54	34.48
CD (p=0.05)	9.28	8.96	0.96	1.35	5.3	3.42	520.7	614.1	2.27	3.44	107.54	78.01

N_0S_0 - No fertilizer and 30 x 5cm spacing
N_0S_1 - No fertilizer and 30 x 10cm spacing
$N_{10}S_0$ - Nitrogen 10 kg/ha and 30 x 5cm spacing
$N_{10}S_1$ - Nitrogen 10 kg/ha and 30 x 10cm spacing

horsegram. Keeping in view the significance of phenological studies in crop-weather interactions, field studies are required to identify the effect of spacing and nitrogen application on crop phenology and heat unit requirements.

Materials and Methods

A field experiment was conducted during 2002-2003 Rabi season at Tamil Nadu Agricultural University Farm, Coimbatore. The treatments comprised of two spacing (30 x 10 cm and 30 x 5 cm) and two levels of N application (10 kg N ha^{-1} and no nitrogen). Effect of the agronomic management treatments on phenological development of horsegram was tested on CO_1 and $Paiyur_1$ varieties. The experiment was laid out in Randomized Block Design with four replications. The entire nitrogen @ 10 kg ha^{-1} was applied at the time of sowing. The crop received three irrigations, at the time of sowing, on 35 and 48 DAS respectively. Two hand weedings were given on 20 and 65 DAS. The crop received rainfall of 144 mm during its growth period. The crop remained free from incidence of major pests and diseases.

Periodical observations on phenological development, growth and yield parameters were recorded. Daily weather data on maximum, minimum temperatures, bright sunshine hours were collected for the study period from Tamil Nadu Agricultural University observatory for computing heat unit requirements for different phenophases of crop growth. The different phenophases at which the heat units computed are sowing to emergence (P1), emergence to branching (P2), branching to flower initiation (P3), flower initiation to 50% flowering (P4), 50% flowering to pod initiation (P5), pod initiation to pod maturity (P6) and sowing to pod maturity (P7).

The heat unit or Growing Degree Day concept assumes a direct and linear relationship between

growth and temperature. A degree day or a heat unit is the mean temperature above base temperature (Iwata, 1984) and it can be expressed as

$$GDD = \left\{ \sum_{i=1}^{n} \left[\frac{T_{Max} + T_{Min}}{2} \right] - T_b \right\}$$

where T_{Max} is maximum temperature of the day, T_{Min} is minimum temperature, and T_b is the lowest temperature at which there is no growth which is also called as base temperature. A base temperature of 10°C was used for calculating GDD in this experiment.

Day and night length is one of the basic factors controlling the period of vegetative growth for photosensitive varieties of crops. Accumulation of heat units is not sufficient to predict developmental stages and maturity in photosensitive varieties. Therefore, photo thermal units are proposed, wherein the degree days are multiplied by length of night in case of short-day plants and length of the day for long-day plants. The basic principle is that flowering is hastened as the length of night increases in short-day plants, while in long-day plants, flowering is delayed as the length of night increases. Similarly, the number of bright sunshine hours is used for calculating accumulated Heliothermal Unit (HTU) requirement for horsegram growth and development. The PTU and HTU was calculated using the following formula.

$$PTU = \sum_{i=1}^{n} (GDD \times \text{length of day})$$

(Major *et al.*, 1975)

HTU = GDD x No. of bright sunshine hours

(Sastry and Chakravarthy 1982)

Results and Discussion

Crop Phenology

The duration of different phenophases of the crop horse gram CO_1 and $Paiyur_1$ with respect to treatments and varieties is presented in Fig 1. The number of days taken by the crop for completion of sowing to pod maturity also varied with treatments and varieties. The crop had maturity period ranging from 95 to 100 days for CO_1 and 98 to 106 days for $Paiyur_1$.

The crop with treatment, no nitrogen and spacing 30 x 5 cm had long vegetative period, which in turn has extended the total growing period. This treatment took longest time of 106 days for $Paiyur_1$ and 100 days for CO_1 for attaining the physiological maturity. The shortest maturity period of 95 days was identified in the treatment with 10 kg nitrogen and with 30 x 5 cm spacing for CO_1 and it was 98 days in the treatment with 10 kg nitrogen and spacing of 30 x 10 cm for the genotype $Paiyur_1$. This is mainly attributed by the nutrients supplied in the form of nitrogen 10 kg ha^{-1} to the crop.

Growing Degree Days and Photo Thermal Units

Growing Degree Days and photo thermal unit are widely used indices for describing the temperature responses to growth and development of crops. Degree day based phenology ie. the thermal time requirement for completion of different phenophase of horse gram for two genotypes with four treatments each were worked out and recorded in Table 1. It was noted that spacing and nitrogen application had marked influence over the degree days accumulated and photo thermal units consumed. For different spacing and nitrogen application, Growing degree days (GDD) for sowing to pod maturity ranged between 1437.6 to 1526.3° C day for CO_1 and 1491.8 to 1633.1°C day for $Paiyur_1$. The mean value of GDD for the same phenophase was 1486.9°C and 1540.1°C day with coefficient of variation of 2.5% and 4.1% for CO_1 and $Paiyur_1$, respectively. The mean GDD worked out at various phenophases showed a highest value at late reproductive phase (pod initiation to pod

maturity), which was 500.3°C for CO_1 and 515.73°C for $Paiyur_1$, followed by vegetative phase (emergence to branching), which was 302.65°C and 295.6°C for CO_1 and $Paiyur_1$, respectively.

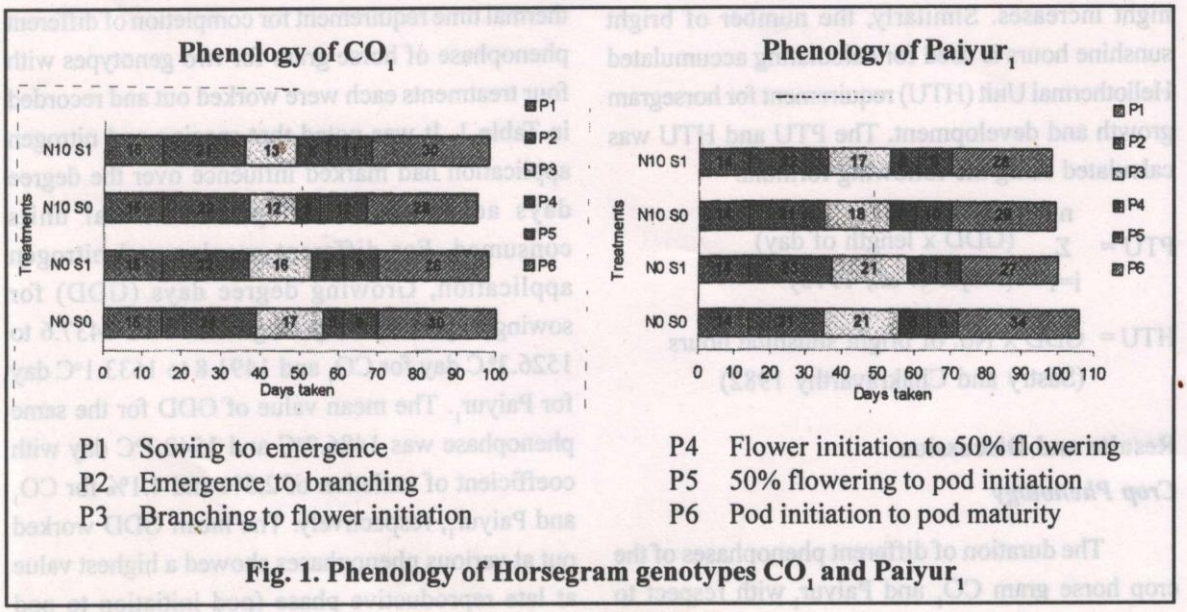
The photo thermal unit (PTU) ranged between 16715.1 to 17764.4°C day hours for CO_1 and 17354.4 to 19048.0°C day hours for $Paiyur_1$. The mean value of PTU for the sowing to pod maturity phase was 17297°C day hours and 17932°C day hours with coefficient of variation of 2.5% and 4.3% for CO_1 and $Paiyur_1$, respectively. Both varieties CO_1 and $Paiyur_1$ were sown on same date on 22th November 2002, having almost same duration (110 days), but required different GDD and PTU to attain maturity. Sengupta *et al.*, (2003), also observed similar results of variation in GDD and PTU between two varieties of Chickpea having same crop duration. Rao *et al.*, (1999) obtained the GDD of Chick pea ranging from 2122°C day to 2678° C day at Hisar, Haryana with a base temperature of 5°C.

Heliothermal Units

The accumulation of Heliothermal units ranged from 11334 to 12176.6 in CO_1 and from 11813.5 to 13290.1 in $Paiyur_1$ for the phenophase P7 (sowing to maturity) with a mean of 11784.2 and 12318.5 for CO_1 and $Paiyur_1$, respectively. Among the treatments, the treatment with no nitrogen and spacing 30 x 5 cm, accumulated more HTU when compared to other treatments for all most all the phenological phases except P4 in CO_1 and P2 in $Paiyur_1$. While comparing the two genotypes, CO_1 consumed 11784.2 HTU from sowing to maturity whereas $Paiyur_1$ consumed 12318.5 HTU for the same.

Field Observations

The results obtained from the field observations are presented in the Table 2. The tabulated data revealed that application of nitrogen 10 kg ha^{-1} and adopting a spacing of 30 x 10 cm recorded the greater plant height, number of branches $plant^{-1}$ and number of pods $plant^{-1}$ in both CO_1 and $Paiyur_1$ varieties. This treatment recorded the plant height of 138.4 cm and 139.4 cm, number of branches of 10.6 and 10.8 and number of pods $plant^{-1}$ of 27.8 and 26.9 for CO_1 and $Paiyur_1$, respectively. With application of N at 10 kg ha^{-1} the



P1 Sowing to emergence
P2 Emergence to branching
P3 Branching to flower initiation
P4 Flower initiation to 50% flowering
P5 50% flowering to pod initiation
P6 Pod initiation to pod maturity

Fig. 1. Phenology of Horsegram genotypes CO_1 and $Paiyur_1$

variety CO_1 planted at two different spacing had no significant influence on plant height and number of branches plant^{-1}. However, in $Paiyur_1$, these two treatments were significantly different for the parameters plant height and number of branches plant^{-1} and were on par with each other for number of pods plant^{-1}.

The results of growth parameters indicated that the treatment with nitrogen 10 kg ha^{-1} and spacing 30 x 10 cm is best than the treatments with no nitrogen and spacing 30 x 10 cm and 30 x 5 cm. The influence of nitrogen application and maintaining plant population of 3,33,333 plants ha^{-1} might have resulted in better crop growth. The nutrients supplied through nitrogen 10 kg ha^{-1} was effectively utilized by 3,33,333 plants ha^{-1} which resulted in better growth. In the treatment with nitrogen 10 kg ha^{-1} and spacing 30 x 5 cm, 6,66,666 plants ha^{-1} shared the same quantity of nitrogen 10 kg ha^{-1} which resulted in lesser growth.

Considering the days to 50 per cent flowering the treatment with nitrogen 10 kg ha^{-1} and spacing 30 x 5 cm enhanced the flowering earlier than other treatments which completed in 55 and 60 days, respectively for CO_1 and $Paiyur_1$ and was on par with the treatment nitrogen 10 kg ha^{-1} and spacing 30 x 10 cm. Application of nitrogen 10 kg ha^{-1} and spacing 30 x 5 cm recorded the greater numbers of pod m^{-2} (1642 and 1454) and grain yield (638.5 kg ha^{-1} and 641 kg ha^{-1}) for CO_1 and $Paiyur_1$, respectively. The reason for higher yield characters by the treatment with nitrogen 10 kg ha^{-1} and spacing 30 x 5 cm might be due to earlier completion of 50% flowering and maintenance of 6,66,666 plants ha^{-1} (50% more population) than the treatment with nitrogen 10 kg ha^{-1} and spacing 30 x 10 cm (3,33,333 plants ha^{-1}).

References

Anon, (2002). *Season and Crop Report of Tamil Nadu.* Published by Department of Economics and Statistics. Chennai, Tamil Nadu, India.

Bhatia, V.S., Manglik, P, Bhatrigar, P.S., Guruprasad, K.N. and Manglik, P. (1997). Variation in sensitivity of soybean genotypes to varying photoperiods in India. *Soybean Genetics Newsletter,* **14** : 99 - 103.

Bogdon, A.V. (1977). Tropical pastures and fodder plants. Longman, London.

Dalton, L.G. (1967). A positive response of yield on maturity of sorghum. *Crop Science,* **7** : 721 - 726.

Iwata, F. (1979). Heat unit concept of crop maturity. In : Physiological aspects of Dryland Farming (Ed. U.S. Gupta). P : 391.

Iwata, F. (1984). Heat Unit concept of crop maturity. In : Gupta U.S. (Ed), Physiological aspects of dry land farming, pp : 351 - 370. Oxford and IBH, New Delhi.

Major, D.J., Johnson, D.R., Tanner, J.W. and Anderson, I.C. (1975). Effects of day length and temperature on soybean development. *Crop Science* **15**, 174 - 179.

Rao, V.U.M., Diwan, Singh and Singh, Raj. (1999). Heat use efficiency of winter crops in Haryana. *Journal of Agrometeorology,* **1**, 2 : 143 - 148.

Sastry, P.S.N. and Chakravarty, N.V.K. (1982). Energy summation indices for wheat crop in India. *Agricultural Meteorology,* **27**: 45-48.

Sengupta, S., Kale, A.A. and Das, H.P. (2003). Assessment of phenology, heat and radiation use efficiency, thermal growth rate and phenophasic development model of chickpea at Peninsular India. *MAUSAM,* **54**, 3 : 711-716.

Wang, J.Y. (1960). A critique of the heat unit approach to plant response studies. *Ecology,* **41** : 785 - 790.

(Received : August 2005 Revised : June 2005)