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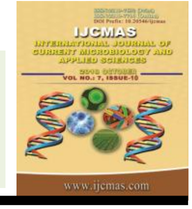

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Thermal Utilization and Heat Use Efficiency of Green Gram Varieties under Different Sowing Dates

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A B S T R A C T

An experiment was conducted on experimental farm at Department of Agril. Meteorology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, during *Kharif* season 2017 entitled “Influence of weather parameters on growth and yield of different genotypes of green gram (*Vigna radiata. L*) under different sowing dates” to study the phenology, accumulation of growing degree days (GDD), helio thermal units (HTU), heat use efficiency (HUE), helio-thermal use efficiency (HTUE) and performance of four sowing dates in main plot including D_1 (24^{th} MW), D_2 (26^{th} MW), D_3 (28^{th} MW) and D_4 (30^{th} MW) with four varieties in sub plot viz. Vaibhav, BM-4, BM-2002-1 and BM-2003-2 in split-plot design for our study purpose and as per package of practices. It was observed that GDDs increased significantly by 56.35 to 139.95 ^{o}C days, in early sowing. The green gram variety Vaibhav accumulated markedly higher GDDs, HTUs and PTU. On mean basis, D_1 (24^{th} MW) produced significantly higher grain yield (970 kg/ha) followed by D_2 (26^{th} MW) (910 kg/ha) whoever genotype BM-2003-2 (819 kg/ha) was significant than rest of varieties. The significant reduction in grain yield was recorded in late sowing date. The GDDs gradually increases from emergence to maturity in all the tested genotype irrespective of sowing date. Green gram genotype BM-2003-2 showed better performance in terms of HUE and HTUE followed by BM-2003-1 and BM-4 varieties giving higher yield, HUE and HTUE are identified under the varying growing environments, so as to suggest the appropriate sowing time of green gram Variety in Parbhani district.

Introduction

Green gram (*Vigna radiata L*. Wilczek) is one of the most important pulse crops of global economic importance. It is locally called as moong or mug and belongs to the family *Leguminoceae*, it fixes atmospheric nitrogen and improves soil fertility by adding 20-25 kg N ha^{-1} (Md Tariqul Islam, 2015). Mung bean has originated in India and is a native of India and central Asia. It is grown in these areas since prehistoric period. Mung bean is grown throughout Southern Asia including India, Pakistan, Bangladesh, Srilanka, China etc. In India green gram is mostly grown in Andhra Pradesh, Maharashtra, Orissa, Rajasthan, Gujarat, Madhya Pradesh, Punjab and Uttar Pradesh etc.

Temperature is one of the primary micro-climatic factors driving rates of growth. Rate of plant growth and development is dependent upon temperature surrounding the plant and each species has a specific temperature range represented by a minimum, maximum, and optimum. These values were summarized by Hatfield *et al.*, (2011) for a number of different species typical of grain and fruit production. The number of days required for cultivars to reach maturity depends primarily on location, date of planting and temperature. Due to variations in daily minimum and maximum temperatures from year to year and between location, number of days from planting to physiological maturity varies and, is not a good predictor of crop development.

Meteorological indices viz. growing degree days (GDD), helio-thermal unit (HTU), and photo-thermal unit (PTU) based on air temperature are used to describe changes in phenological behavior and growth parameters (Paul *et al.*, 2000; Girijesh *et al.*, 2011; Prakash *et al.*, 2015). The temperature based agrometeorological indices provide a reliable prediction for crop development and yield.

Influence of temperature on phenology and yield of crops can be studied under the field condition through accumulated heat unit system (Pandey *et al.*, 2010). Duration of crop/cultivars is a genetic attributes, and is influenced by environmental condition, which varies with location and years in which it is grown because the rate of development is largely influenced by the temperature and photoperiod. Plants have a definite heat requirement before they attain certain phenophases. A change in temperature during phenophases of a crop adversely affects the initiation and duration of different phenophases and finally the economic yield. It is therefore, indispensable to have knowledge of the exact duration of phenophases in a particular environment and their association with yield attributes for achieving the higher yield, hence keeping above in view the present investigation was carried out.

Materials and Methods

An experiment was conducted on experimental farm at Department of Agril. Meteorology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, during *Kharif* season 2017, Parbhani (19^0 16' North latitude and 76^0 47' East longitude and at an altitude of 409 meter above mean sea level (MSL)). The treatments comprised of four dates of sowing viz. D_1 (24^{th} MW), D_2 (26^{th} MW), D_3 (28^{th} MW) and D_4 (30^{th} MW) with four varieties in sub plot viz. Vaibhav, BM-4, BM-2002-1 and BM-2003-2 in sub plot were replicated thrice in a split plot design. All cultural operations and plant protection measures were followed as per the recommendations contained in package of practices. Meteorological data were recorded from Agrometeorological Observatory, Department of Agricultural meteorology college of Agriculture, VNMKV, Parbhani. The grain, straw and biological yields were recorded as per treatments and expressed in kg ha^{-1}. Growing degree days (GDD), helio thermal units (HTU), photo thermal units (PTU), heat use efficiency (HUE), and helio thermal use efficiency were computed using the daily meteorological data. The base temperature of 10 °C was used for computation of GDD on daily basis (Leong and Ong, 1983). Agro-meteorological indices were computed for different phenophases of crop (emergence, Bud emergence, Flower emergence, Pod emergence and Harvest) by adopting. Data were analyzed with analysis of variance (ANOVA) as standard method. Treatments were compared by computing the F-test. The significant differences between treatments were compared pare wise by critical difference at the 5 per cent level of probability.

Results and Discussion

Phenology

In general attributes of green gram varieties were markedly influenced with sowing dates (Table 1). The D_2 (26^{th} MW) sown crop significantly required to more number of days required for 50 per cent flowering (40 days) and followed by D_1 (24^{th} MW) (38 days), D_4 (30^{th} MW) (37 days) and D_3 (28^{th} MW) (35 days) and varieties V_1 (Vaibhav) (39 days) followed by (BM-2002-1), (BM-2003-2) and (BM-4) however same trend was recorded in case of days to maturity. This might be due to the fact that sowing time determines time available for vegetative phase before onset of flowering, which is mainly influenced by the photoperiod.

Days to 50 per cent flowering and days to maturity differed significantly among the green gram varieties and same trend was followed in days to maturity, whereas the D_1 (24^{th} MW) (71 days) more days required to maturity as compare to rest of sowing date and varieties V_1 (Vaibhav) (74 days) followed by (BM-2003-2), (BM-2002-1) and (BM-4). The variation in phenology of green gram varieties was also reported by Taleei *et al.,* (1999).

Yield attributes

The yield parameters of green gram varieties markedly influenced with sowing dates (Table 1). Grain and straw yields of green gram variety were significantly higher with D_1 (24^{th} MW) sown crop (970 Kg ha^{-1}) and respective increase was 6.6 per cent, 51.1 per cent and 130 per cent over D_2 (26^{th} MW), D_3 (28^{th} MW) and D_4 (30^{th} MW) respectively. Higher seed yield was realized in case of D_1 (24^{th} MW) sown crop because of higher growth and yield attributed which lead to higher yield of the respective treatments. Grain and straw yield differed significantly among the green gram varieties. The green gram varieties (BM-2003-2) recorded significantly higher grain yield (819 Kg ha^{-1}) followed by (BM-2002-1) (753 Kg ha^{-1}) and the lowest with (BM-4) (666 kg ha^{-1}).

However Straw and biological yield significantly highest in D_1 (24^{th} MW) and (BM-2003-2) as compare to rest of treatments. This might be due to more growth attributes like more plant population, no of green leaves, dry matter and leaf area was recorded more with the respective treatments Taleei *et al.*, (1999).

Heat use efficiency and helio thermal use efficiency

At maturity, HUE for grain and straw production was significantly higher (0.52 and 1.10 kg/ha ^{0}C day) for D_1 (24^{th} MW) sown crop as compared to rest of sowing dates sown crop (Table 2). Among varieties, (BM-2003-2) had significantly higher heat use efficiency (0.44 kg/ha ^{0}C day) followed by BM-2002-1 (0.41 kg/ha ^{0}C day), BM-4 (0.39 kg/ha ^{0}C day) and Vaibhav (0.35 kg/ha ^{0}C day) for grain production, whereas, same trend was followed in straw and biological yield. Helio thermal use efficiency for grain and straw was found maximum 0.10 and 0.21, respectively for D_1 (24^{th} MW) sown crops. In case of varieties, BM-2003-2 had highest helio-thermal use efficiency 0.09 and 0.19, respectively for grain and straw production.

The minimum helio thermal use efficiency was found in Vaibhav for grain as well as straw production. Higher HUE and HTUE in timely sown could be attributed to the highest grain and straw yield. As the temperature was optimum throughout growing period crop utilized heat more efficiently and increased biological activity that confirm higher yield. Similar relationship was expressed by Thavaprakash *et al.,* (2007).

Table.1 Yield and yield attributes of green gram varieties under different thermal environments

Treatment	Days to 50% flowering	Days to Maturity	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Sowing dates (D)					
D_1 (MW 24)	38.0	71.0	970	2060	3030
D_2 (MW 26)	40.0	69.0	910	1949	2859
D_3 (MW 28)	35.0	69.0	642	1529	2171
D_4 (MW 30)	37.0	66.0	421	1088	1508
SE ±	0.62	0.57	22.74	50.06	69.61
CD at 5 %	1.82	1.69	78.69	173.25	240.90
Varieties (V)					
V_1 (Vaibhav)	39.0	74.0	703	1625	2322
V_2 (BM-4)	36.0	65.0	666	1596	2270
V_3 (BM-2002-1)	37.5	67.0	753	1652	2391
V_4 (BM-2003-2)	37.5	69.0	819	1753	2585
SE ±	0.75	0.64	18.19	41.87	61.05
CD at 5 %	2.19	1.97	54.55	125.53	183.03
Interaction (D X V)					
SE ±	1.50	1.21	47.96	64.49	167.03
CD at 5 %	NS	NS	NS	NS	NS
Mean	37.50	68.8	736	1656	2392

Table.2 Heat use efficiency (HUE) and Helio thermal use efficiency (HTUE) of different

Treatment	HUE (Kg ha^{-1} ^{o}C day)			HTUE (Kg ha^{-1} ^{o}C day)		
	Seed Yield	Straw Yield	Biological Yield	Seed Yield	Straw Yield	Biological Yield
Dates of sowing						
D_1 (MW 24)	0.52	1.10	1.62	0.10	0.21	0.32
D_2 (MW 26)	0.50	1.07	1.57	0.10	0.22	0.33
D_3 (MW 28)	0.37	0.87	1.24	0.08	0.18	0.26
D_4 (MW 30)	0.24	0.63	0.87	0.04	0.11	0.15
Varieties						
V_1 (Vaibhav)	0.35	0.82	1.17	0.07	0.16	0.23
V_2 (BM-4)	0.39	0.93	1.33	0.08	0.19	0.26
V_3 (BM-2002-1)	0.41	0.91	1.31	0.08	0.18	0.26
V_4 (BM-2003-2)	0.44	0.95	1.40	0.09	0.19	0.28

Table.3 Phenophase wise Agrometeorological indices required as influenced by various treatments of green gram during *Kharif* season sowing dates and Varieties

Treatments	Photo thermal index					
	P_1	P_2	P_3	P_4	P_5	Total
Dates of sowing						
D_1(MW 24)	28.0	28.0	25.6	25.8	26.5	26.8
D_2(MW 26)	27.6	26.1	26.8	25.9	25.9	26.3
D_3 (MW 28)	24.6	26.7	26.5	23.8	26.5	26.1
D_4 (MW 30)	26.4	26.3	25.1	25.6	27.0	26.3
Varieties						
V_1 (Vaibhav)	26.9	26.8	26.2	25.6	26.5	26.4
V_2 (BM-4)	26.6	26.7	25.9	25.3	26.5	26.3
V_3 (BM-2002-1)	26.4	26.8	26.1	25.1	26.5	26.4
V_4 (BM-2003-2)	26.8	26.8	26.0	25.5	26.4	26.4
Growing degree days (^{0}C days)						
Dates of sowing						
D_1(MW 24)	195.8	476.2	281.5	206.0	714.9	1874.5
D_2(MW 26)	304.1	469.7	241.6	155.3	647.5	1818.1
D_3 (MW 28)	147.8	400.3	291.4	166.4	741.8	1747.7
D_4 (MW 30)	184.9	421.2	300.8	153.8	673.8	1734.5
Varieties						
V_1 (Vaibhav)	242.2	455.5	340.2	230.8	714.7	1983.4
V_2 (BM-4)	186.2	400.8	259.4	177.3	687.8	1711.5
V_3 (BM-2002-1)	158.2	428.2	313.2	150.6	768.4	1818.5
V_4 (BM-2003-2)	214.2	482.9	286.3	204.1	661.0	1848.5
Helio thermal unit (^{0}C day hours)						
Dates of sowing						
D_1(MW 24)	1585.9	3095.3	534.9	947.6	3431.8	9595.5
D_2(MW 26)	1976.3	1221.2	1811.6	450.4	3302.3	8761.8
D_3 (MW 28)	236.5	2321.5	1282.2	349.4	4228.3	8417.8
D_4 (MW 30)	1331.6	1642.7	1233.3	1338.1	4244.6	9790.3
Varieties						
V_1 (Vaibhav)	1356.5	2141.0	1530.7	1061.8	3859.3	9949.2
V_2 (BM-4)	1042.6	1883.6	1167.1	815.7	3714.3	8623.3
V_3 (BM-2002-1)	885.6	2012.4	1409.5	692.6	4149.1	9149.2
V_4 (BM-2003-2)	1199.5	2269.8	1288.3	938.8	3569.4	9265.8
Photo thermal unit (^{0}C day hours)						
Dates of sowing						
D_1(MW 24)	2590.4	6295.4	3710.2	2702.7	9251.45	24550.13
D_2(MW 26)	4016.5	6176.6	3285.1	1994.1	8054.90	23527.08
D_3 (MW 28)	1946.5	5347.3	3767.8	2083.3	9146.39	22291.37
D_4 (MW 30)	2519.0	5391.4	3741.9	1897.9	8293.86	21844.08
Varieties						
V_1 (Vaibhav)	3221.7	5981.2	4432.2	2931.7	8933.5	25500.2
V_2 (BM-4)	2476.2	5262.1	3379.3	2251.9	8598.0	21967.6
V_3 (BM-2002-1)	2103.4	5621.7	4081.3	1912.1	9604.5	23322.9
V_4 (BM-2003-2)	2848.9	6340.9	3730.4	2591.8	8262.5	23774.4

P_1: Sowing to Germination; P_2: Germination to Bud emergence; P_3: Bud emergence to Flower emergence; P_4: Flower emergence to Pod emergence; P_5: Pod emergence to Harvest

Agrometeorological indices

The agrometeorological indices (GDD, HTU, PTI and PTU) during different phenophases of green gram are presented in (Table 3). The D_1 (24th MW) sown crop took longer duration for maturity and crop took more days to fulfill the thermal requirement than the rest of sowing dates. Photo thermal index was highest for D_1 (24th MW) sown crops at all the phenophases (Table 1), the total PTI value of which was significantly higher (26.8 ^oC) in D_1 (24th MW) sown crop followed by D_2 (26th MW), D_4 (30th MW) and D_3 (28th MW) respectively and PTI values was not more difference in among the varieties.

The total accumulated GDD and PTU during the maximum reproductive stage of the crop decreased from 673.8 ^oC days and 8293.9 ^oC days' hr under D_4 (30th MW) sowing to 714.9 ^oC days and 9251.5 ^oC days' hr under timely sowing on D_1 (24th MW), respectively. D_1 (24th MW) sown crop accumulated more heat unit (1874.5^oC days) to reach maturity followed by D_2 (26th MW) (1818.1 ^oC days), D_3 (28th MW) (1747.7 ^oC days) and D_4 (30th MW) (1734.5 ^oC days).one month delay in sowing from D_1 (24th MW) (early sown) to D_4 (30th MW) (delay sown) increased the accumulated heat units and photo-thermal units by 140 ^oC days and 2706 ^oC days' hr, respectively. Among the varieties, Vaibhav had higher heat units (1983.4 ^oC days) and photo-thermal units (25500.2 ^oC days hr), which might be due to significantly higher number of days taken to maturity lowest by BM-4 (1711.5 ^oC days and 21967.6 ^oC days hr). This might be due to better growing conditions such as temperature, light, humidity and rainfall to fully exploit genetic potentiality of crop (Bahar *et al.*, 2015).

The total accumulated HTU during the maximum reproductive stage of the crop increase from 3431.8 ^oC days' hr under D_1 (24th MW) sowing to 4244.6 ^oC days' hr under delay sowing on, D_4 (30th MW) respectively. D_4 (30th MW) sown crop accumulated more HTU (9790.3 ^oC days hours) to reach maturity followed by D_1 (24th MW) (9595.5 ^oC days hours,) D_2 (26th MW) (8761.8 ^oC days hours) and D_3 (28th MW) (8417.8 ^oC days) respectively. Among the varieties, Vaibhav had higher HTU (9949.2 ^oC days hours) and followed by BM-2003-2, BM-2002-1 and BM-4 respectively.

Based on the above findings, it may be concluded that D_1 (24th MW) produced higher grain yield (970 kg/ha) as compare to other sowing dates however among varieties BM-2003-2 produced higher grain yield (819 kg/ha) followed by BM-2002-1, Vaibhav and BM-4 respectively. On an average, timely sown variety produced the maximum grain. The variety BM-2003-2 showed stable yield in almost both the sowing dates and performing overall best in terms of utilization of HUE and HTUE. The growing degree day, photo-thermal unit and photo-thermal index for entire crop growing period decreased with delayed sowing. This study also indicated that change in microclimate due to different sowing time is reflected in individual phonological stage. Differences in agro-meteorological indices for various phonological stages indicated that accumulated temperature can be utilized for dry biomass and crop yield forecast.

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