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EFFECT OF VARIETY AND HEAT STRESS AT DIFFERENT PLANTING DATES ON MUNGBEAN YIELD AND YIELD COMPONENTS

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Abstract

In order to determine the impact of heat stress effects in different planting dates on mungbean varieties field trials were conducted in clay soil in Qalubia governorate, during 2017 and 2018 summer seasons. Kawmy^{-1} and V2010 varieties were sown at 5 dates every two weeks namely, 15/5 (D1), 1/6 (D2), 15/6 (D3), 1/7 (D4) and 15/7 (D5). The mean minimum and maximum temperatures during each planting date were (17.0 – 27.0), (19.5 - 31.5), (23.0 - 36.5), (23.5 - 37.5) and (25.0 - 38.0) for D1, D2, D3, D4 and D5, respectively. The results showed that Kawmy-1 surpassed V2010 in plant height, number of pods palnt^{-1}, seed yield plant^{-1} as well as seed yield ha^{-1} in the 1st and 2nd harvests at 80 and 100 days after sowing respectively and total seed yield ha^{-1}. Regardless planting date Kawmy^{-1} was earlier in 50% flowering period and produced > 50% of sed yield plant^{-1} and seed yield ha^{-1} of the total seed yield at the 1st harvest (80 days after sowing) compared with V2010. There were not significant effects among different planting dates in flowering until 1/7 planting date (D4) thereafter, the flowering duration was significantly shortened. Plant height was not affected till 1/6 planting date (D2) thereafter, it was gradually declined. The best seed yield ha^{-1} was attained at 15/5 and 1/6 planting dates (D1 and D2), and in the subsequent planting dates it reduced gradually in the later planting dates. The planting date 15/5 (D1) gave the highest seed yield ha^{-1} and surpassed D2 without significant differences among D2 and D3, D4 and D5 in the total seed yield ha^{-1}. The interaction between variety and planting date showed that Kawmy^{-1} was superior in seed yield ha^{-1} when it was sown either in D1 (15/5) or D2 (1/6) followed by V2010 when it was planted at D1. There were gradual increase in the mean minimum or maximum temperatures over D1 planting date as planting dates advanced. Mean temperatures increased by 2.5-8 ^{o}C and 4.5-11 ^{o}C for the minimum and maximum temperatures for D2 - D5 as compared with the best planting date D1. The yield reduction percentage was nearly doubled for Kawmy-1 when the minimum temperature raised by 1^{o}C, meanwhile, and reached 3 folds when the maximum temperature raised by 1^{o}C. These results confirm the sensitivity of Kawmy^{-1} to the increase either of minimum or maximum temperatures in D2 to D5 planting dates. Heat stress indices showed that Growing degree days GDD (ºC day) for mungbean crop was 1000 units (90 days to physiological maturity), and the accumulated GDDs for the other planting dates ranged between 1100 and 1250 unites for D2 to D5, respectively. were 1590 units (90 days to physiological maturity). Helio thermal unit (Degree-days hours) HTU for mungbean crop during different planting dates were 9000, 10510, 11542, 12812 and 11756 units for D1, D2, D3, D4 and D5, respectively. Meanwhile, Photo-thermal unit (Degree-days hours) PTU for mungbean in different planting dates were 16000, 17700, 19440, 20500 and 19800 units (80 days to physiological maturity for D1, D2, D3, D4 and D5, respectively. Photo-thermal Index (PTI) for both varieties were similar and ranged between 23.2 to 32.5 °C for V2010 and 27.6 to 33.0 °C for Kawmy-1. PTI gradually increased as planting dates retarded for both varieties. Heat use efficiency (Kg ha^{-1} degree days) HUE were 1.65 kg seed ha^{-1} degree day^{-1} for V2010 and 2.44 kg seed ha^{-1} degree day^{-1} for Kawmy-1. HUE shows lower values as planting dates retarded and such reductions were gradual from D2 to D5 compared with D1 the best planting date. It could be concluded from this study that mungbean is among the most temperature sensitive crops and production could fluctuate with a slight change in temperature which could be observed from the lower yields in the later planting dates compared with the best planting date D1.

***Keywords* :** Planting dates, Yield, Heat Stress, Temperature.

Introduction

There is a shortage in edible summer legumes in Egypt and introducing of high yielding food crops with short growing season in the crop pattern is considered to be an effective mean for narrowing the food gap in Egypt (Ashour *et al.*, 1995). Mungbean or green gram (*Vigna radiata* L. Wilczek) is a short duration (65 - 90 days) grain legume having wide adaptability and low input requirements (Nair *et al.*, 2012) (Bindumadhava *et al.*, 2018). When the nutritive value of mungbean seeds is compared with other pulse crops cultivated in Egypt, it can be noticed that mungbean surpasses lentil and broad bean in Ca, Fe and vitamin A. The protein content is more or less the same for the three pulses (Ashour *et al.*, 1993), it is considered it is considered as poor men's protein (Mian, 1976). Increasing atmospheric temperatures will be detrimental for growth functions of various crop plants, more so in mungbean. Mungbean mean temperature of 20 to 22 ^{o}C may be the minimum for productive growth with the mean optimum temperature in the regime of 28 to 30 ^{o}C. Lawn and Ahn (1985) reported that varieties of mungbean differ insensitively to maximum and minimum temperature. Khairnar *et al.* (2003) Increasing atmospheric temperatures will be detrimental for growth functions of various crop plants, more so in mungbean.

Among the various agronomic practices, planting time the most important factor influencing the yield of mungbean, Bari 1998. A significant effect of planting time on seed yield was found in mungbean, Bari, (1999). Sarkar *et al.* (2004) observed that early planted (3 and 18 February) crops produced higher yield as compared to late planted (5 and 20 March) crops. Miah *et al.* (2009) identified the suitable variety and optimum sowing date for getting maximum yield of summer mungbean. They found varietal differences and planting dates affected yield and the highest seed yield (969.62 kg ha^{-1}) was obtained from 2 March sowing followed by 20 February (917.54 kg ha^{-1}) and 12 March sowing (869.52 kg ha^{-1}). Sowing after 2 March gradually decreased the seed yield producing the lowest value. Miah *et al.* (2009)

reported that the Interaction between variety and sowing date significantly influenced all the yield contributing characters (except 1000-seed weight) and yield of summer mungbean. Naveed *et al.* (2015 evaluated the effects of different planting dates on the performance of mungbean cultivars under rainfed conditions, consisting of eight planting dates and reported that Maximum plant height, pods plant^{-1}, pod length, seeds pod^{-1}, 1000 grain weight, seed yield belonged to June 2nd planting followed by May 26th while beyond this, there was a gradual decrease in yield and relevant components. Heat stress has harmful effects at several levels of plant functions, leading to a drastic reduction in growth rates and yield traits (Wahid *et al.*, 2007). In leaves, photosynthetic mechanism is recognized sensitive to elevated temperatures. Sinsawat *et al.* (2004) indicated that Photosynthesis may be inhibited due to heat stress and Reproductive tissues and their functions are highly sensitive to heat stress, and a few degrees raise in temperature during flowering can lead to loss of entire grain crop cycles (Wheeler *et al.*, 2000; Asseng *et al.*, 2011 and Hatfield *et al.*, 2011). Chikukura *et al.* (2017) reported that elevated temperatures > 44/34 °C significantly affected net photosynthesis at all stages. Moreover, a departure from the normal seasonal temperatures by 8-10 °C resulted in shortened phenological stages specifically vegetative phase leading to earlier maturity (50-57 DAS) compared to the control that reached maturity between 70-77 DAS under normal summer seasonal temperature. Heat stress indices Growing degree days, Helio thermal unit (Degree-days hours, HTU Photo-thermal unit PTU (ºC day) and Heat use efficiency HUE were suggested by Monteith (1984). Kumar (2017) studied heat stress indices of urd and wheat and reported that mean GDD, HTU, PTU for wheat and urd crops were 2016, 14383, 22745 and 1592, 8586, 20813, respectively. They recommended that Physiological maturity can be predicted for wheat and urd by using GDD, HTU, PTU with R2 0.98 and 0.99 respectively. He reported that during 2007 the HUE for urd was 1.18 kg grain ha^{-1} degree days^{-1} with grain yield 1878 kg ha^{-1} and during 2008 HUE was 0.99 kg grain ha^{-1} degree days^{-1} with grain yield 1584 kg ha^{-1}.

The aim of this work is to find the impact of variable heat regimes created from different planting dates on growth and yield of mungbean as a new crop under Egyptian conditions.

Materials and Methods

In order to determine the proper heat regime for growing mungbean as a new crop under Egyptian conditions during the summer season, field experiments were conducted in clay soil in Qalubia governorate in 2017 and 2018 summer seasons. The experimental soil was clay in texture with pH 7.8, OM 1.28 %, N 0.47 %, P 0.48 % and K 0.27%. (Average of two seasons). Kawmy^{-1} and V2010 varieties were sown at 5 dates every two weeks namely, 15/5 (D1), 1/6 (D2), 15/6 (D3), 1/7 (D4) and 15/7 (D5) in both seasons. The mean minimum and maximum temperatures during each planting date in both seasons (Fig. 1) were (17.0 – 27.0), (19.5 - 31.5), (23.0 - 36.5), (23.5 - 37.5) and (25.0 - 38.0) for D1, D2, D3, D4 and D5, respectively. The soil was ploughed twice, ridged and divided into experimental plots. The experimental design was split plot, the planting dates occupied the main plots and the sub plots were assigned to the varieties, the plot area was 21 m^2 and each contained 5 rows 6 meter long and the distance between rows 0.7 m. Mungbean seeds were sown in hills 10 cm apart. Sowing was done by dry seeds in dry soil method at the experimented planting dates. After complete germination, the plants were thinned and one healthy plant per hill was left to grow.

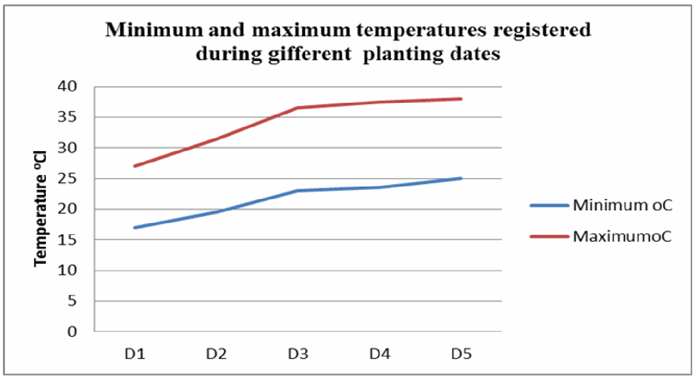

Fig. 1: Minimum and maximum temperatures registered during planting dates

During seed bed preparation, calcium super phosphate (15.5 %) was applied at the rate of 37 kg P_2O_5 ha^{-1}. Before the 1st irrigation, nitrogen fertilizer as ammonium sulphate (20.6 % N) was applied at the rate of 72 kg nitrogen ha^{-1} and potassium was applied at 60 kg K_2O ha^{-1}.

Irrigation was applied according to the recommended practice for irrigation in the district. During the growing season two ridges were labeled and the number of days to 50 % flowering was recorded. Harvest was carried out twice after 80 and 100 days from sowing. At the second harvest, four guarded hills (8 plants) were labeled and the following parameters were registered:

1- Plant height (cm).

2- Number of branches plant^{-1}.

Yield components characters:

3- Number of pods plant^{-1} at 80 and 100 days from sowing and total number of pods plant^{-1}.

4- 1000-seeds weight (g).

5- Seed yield per plant (g) at 80 and 100 days from sowing and total seed yield plant^{-1}.

6- Harvest index.

7-Seed yield ha^{-1}.

Two ridges were devoted for pod collecting twice at 80 and 100 days to determine seed yield in each of the two harvest times as well as the total seed yield ha^{-1} (kg). In order to determine the actual reduction of seed yields per plant and per hectare due to heat effect, the difference in optimum minimum and maximum temperature from the best planting date reported was calculated and the reduction in these criteria in other planting dates were determined relative to the optimum heat regime reported for 1°C. Since the best seed yield for the planting date was 15/5 (D1) the differences in minimum and maximum temperatures for the other planting dates D2, D3, D4 and D5 were calculated and yield reduction per 1°C was calculated. The earliness character was determined as follows in the different planting dates:

Earliness % = Seed yield kg ha^{-1} in the 1st harvest / Total seed yield ha^{-1}

Heat Stress Indices

Growing degree days at different phenological stages were calculated by summation of daily mean temperature above base temperature for a corresponding period from sowing, as suggested by Monteith (1984). Helio thermal unit was calculated using the formula given by Rajput (1980).

1. **Growing degree days (Degree days)**: Growing degree days was computed with 17 ºC as base temperature on the basis of daily mean temperature with the help of following formula:

$$GDD = \Sigma \frac{(T\ max + T\ min)}{2} - Tb$$

2. **Helio thermal unit (Degree-days hours):** Halio-thermal unit was calculated on the basis of GDD and sunshine hours by the following formula:

$$HTU = GDD \times \text{Duration of sun shine hours}$$

3. **Photo-thermal unit (Degree-days hours)**: Photo-thermal unit was calculated on the basis of GDD and day length with the formula given below:

$$PTU = GDD \times \text{Day length}$$

4. **Photo-thermal index (Degree-days day^{-1}):** Photo thermal index was calculated using the following equation:

$$PTI = GDD / \text{Growth days}$$

5. **Heat use efficiency (Kg ha^{-1} degree days)**: Heat use efficiency was calculated with the help of seed yield (kg ha^{-1}) per GDD with the help of following equation:

$$HUE = \text{Seed yield (kg ha}^{-1}) / GDD$$

6. **Relative temperature depression (%):** Relative temperature depression was calculated using the formula:

$$RTD = \frac{\Sigma\ Tmax - Tmin}{Tmean}$$

The analysis of variance of split plot experiment was carried out using MSTAT-C Computer Software (MSTAT-C, 1988), after testing the homogeneity of the error according to Bartlett's test, combined analysis for both seasons were done. Means of the different treatments were compared using the least Duncan’s Multiple Range Test at 0.05 level.

Results

Effect of variety

Data presented in Table (1) show the superiority of Kawmy^{-1} than V2010 in plant height, number of pods palnt^{-1}, seed yield plant^{-1} as well as seed yield ha^{-1} in the 1st and 2nd harvests at 80 and 100 days after sowing, respectively and total seed yield ha^{-1}. However, V2010 exceeded Kawmy^{-1} in seed index. Regardless planting date Kawmy^{-1} flowered earlier and produced > 50% of seed yield plant^{-1} and seed yield ha^{-1} of the total seed yield at the 1st harvest (80 days after sowing) compared with V2010.

Table 1: Effect of mungbean variety on yield characteristics.

Variety	No. of days to 50% Flowering	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}			Seed yield plant^{-1} (g)			Seed index g	Seed yield ha^{-1} (kg)		
				80 days	100 days	Total	80 days	100 days	Total		80 days	100 days	Total
V2010	42.7 a	80.3 a	5.7 a	13.2b	9.9b	23.1b	6.1b	5.8b	11.9b	67.7a	1092b	751b	1843b
Kawmy^{-1}	41.8 a	87.3 a	5.6 a	25.8a	16.5a	42.3a	8.9a	7.7a	16.6a	46.3b	1459a	1245a	2704a

Effect of planting date:

Data in Table (2) show significant effects of planting date on plant height, number of pods plant^{-1}, seed yield plant^{-1} and seed yield ha^{-1} at 80 and 100 days from sowing. Generally, the data reveal that there were not significant effects in flowering until 1/7 planting date (D4) thereafter, the flowering duration was significantly shortened. Plant height was not affected till 1/6 planting date (D2) and then, it was gradually declined. Seed index was significantly affected by the different plant dates and the best seed index was obtained at 15/5 (D1) planting date. Regarding seed yield plant^{-1}, it can be noticed that it was not affected until 15/6 planting date (D3) at the 1st harvest after 80 days from sowing and till 1/6 planting date (D2) at the 2nd harvest after 100 days from sowing, then gradual reductions in seed yield plant-1 were reported. The best seed yield ha^{-1} was attained at 15/5 and 1/6 planting dates (D1 and D2), but it reduced gradually in the later planting dates. Concerning the total seed yield ha^{-1}, it is clear that planting date 15/5 (D1) gave the highest seed yield ha^{-1} and surpassed D2 meanwhile the differences among D2 and D3, D4 and D5 in the total seed yield ha^{-1} were insignificant.

Table 2: Effect of mungbean planting date on yield characteristics.

Planting date	No. of days to 50% flowering	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}			Seed yield plant^{-1} (g)			Seed index (g)	Seed yield ha^{-1} (kg)		
				80 days	100 days	Total	80 days	100 days	Total		80 days	100 days	Total
D1 (15/5)	43.9 a	95.4 a	5.5 b	22.8 a	17.8 a	40.6 a	8.7 a	7.9 a	16.6 a	60.8 a	1819 a	1272 a	3091 a
D2 (1/6)	44.1 a	90.6 a	5.3 b	18.4 b	12.6 c	31.0 b	8.0 a	7.7 a	15.7 a	56.7 b	1678 a	1178 ab	2856 b
D3 (15/6)	42.1 ab	76.6 b	7.5 a	18.2 b	15.6 b	33.8 b	8.3 a	6.9 ab	15.2 a	57.5 b	1102 bc	667 c	1769 c
D4 (1/7)	41.7 ab	78.3 b	5.3 b	22.8 a	16.0 a	38.8 a	6.8 b	5.6 b	12.4 b	55.3 bc	816bc	943bc	1759 c
D5 (15/7)	39.8 b	80.0 b	5.0 b	20.3 b	17.7 a	38.0 a	5.7 b	5.7 b	11.4 b	54.6 c	826 c	814 c	1640 c

Effect of the interaction (Variety × Planting date)

The interaction between variety and planting date on No of pods plant^{-1} at the 1st and 2nd harvest (80 and 100 days after sowing) as well as seed index as well as seed yield ha^{-1} was significant (Table 3). In general, Kawmy^{-1} was superior in seed yield ha^{-1} when it was sown either in D1 (15/5) or D2 (1/6) followed by V2010 when it was planted at D1 (15/5).

Table 3: Effect of the interaction between variety and planting date on mungbean yield characteristics.

Variety	Planting date	Flowering %	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}			Seed yield plant^{-1} (g)			Seed index (g)	Seed yield ha^{-1} (kg)		
					80 days	100 days	Total	80 days	100 days	Total		80 days	100 days	Total
V2010	D1 (15/5)	44.1 a	92.0 b	5.5 b	12.5 c	9.9 de	22.4c	7.6 bc	6.8 b	14.4 b	69.9a	1643 ab	1012 bc	2655b
	D2 (1/6)	45.3 a	85.0 c	5.0 b	10.2 c	8.3 e	18.6d	6.5 c	7.4 ab	13.9 b	68.8a	1284 b	986 c	2270 b
	D3 (15/6)	42.7 b	71.8 e	7.9 a	10.8 c	8.8 e	19.6d	6.4 c	6.1 b	12.5 bc	68.2a	882 c	606 d	1488 c
	D4 (1/7)	41.4 b	72.5 e	5.5 b	14.3 c	11.5 d	25.8c	5.2 cd	4.5 c	9.7 c	66.3a	941 c	512 e	1453 c
	D5 (15/7)	40.2 c	80.0 d	4.5 c	18.0 bc	11.0 d	29.0c	4.9 d	4.3 c	9.2 c	65.4a	718d	648 d	1366 c
Kawmy^{-1}	D1 (15/5)	43.6 a	98.8 a	5.4 b	23.0 b	20.0 b	43.0b	9.8 a	9.0 a	18.8a	51.7b	1993 a	1722 a	3715 a
	D2 (1/6)	42.8 a	95.2 ab	5.5 b	26.5 ab	16.8 c	43.3b	9.5 a	8.0 a	17.5a	44.6c	2070 a	1372 b	3442 a
	D3 (15/6)	41.5 b	81.3 d	7.0 a	25.5 ab	22.3 ab	47.8a	10.2 a	7.7 a	17.9a	46.8 c	1321 b	1014 b	2335 b
	D4 (1/7)	41.9 b	81.3 d	5.0 b	31.3 a	20.4 b	51.7a	8.4 b	6.7 b	15.1cb	44.5c	977 c	1135 b	2112 b
	D5 (15/7)	39.4 c	80.0 d	5.0 b	22.5 b	23.8 a	46.2a	6.5 cd	7.0 b	13.5ab	43.7c	932 c	982 c	1914 bc

Effect of heat stress

Data in Table (4) reveal that there were gradual increase in the mean minimum or maximum temperatures over D1 planting date as planting dates advanced. mean temperatures increased by 2.5-8 °C and 4.5-11 °C for the minimum and maximum temperatures for D2-D5 as compared with the best planting date D1. From the same table, it is clear that except the latest planting dates D4 and D5 for Kawmy-1, both varieties out yield more than 50 % of the total seed yield at the 1st harvest (80 days after sowing). V2010 seems to be slight earlier in maturing than Kawmy^{-1} in D1. The data indicate that although Kawmy^{-1} yielded more than V2010 in D4 and D5 the earliness % was lower due to the high yielding ability of Kawmy^{-1}. The total yield reduction reported due to the increase in both minimum and maximum temperatures were 384, 1166, 1201 and 1288 kg ha^{-1} for the variety V2010 in D2, D3, D4 and D5, respectively, while the corresponding values for Kawmy-1 were 273, 1380, 1603 and 1798 for D2, D3, D4 and D5 planting dates respectively. These reductions represented 14.5, 43.9, 45.2 and 48.5 for V2010 and 7.3, 37.1, 43.1 and 48.2 for Kawmy-1 in D2, D3, D4 and D5, respectively as compared with the best planting date (D1). From the same table and Figs. (2 - 4), it clear that seed yield reduction due to the increase in temperature as planting dates retarded from D2 to D5 and it was more pronounced for Kawmy-1 than V2010 indicating the greater sensitivity of Kawmy^{-1} to the increase in minimum or maximum temperature. Such tendency was true when the minimum temperature raise by 1 °C the yield reduction of V2010 ranged between 153.6-194.8 kg ha^{-1} while the yield reductions occurred when the minimum temperature raised by 1 °C ranged between 109-230 kg ha^{-1} for Kawmy^{-1} from D2 to D5 as compared with the best planting date (D1). It is worthy to note that the yield reduction percentage was nearly doubled for Kawmy^{-1} when the minimum temperature raised by 1 °C, meanwhile, and reached 3 folds when the maximum temperature raised by 1 °C. These results confirm the sensitivity of Kawmy^{-1} to the increase either in minimum or maximum temperatures from D2 to D5 planting dates.

Table 4: Effect of the interaction between variety and planting date on mungbean seed yield reduction, earliness, Photo-thermal index and heat use efficiency.

Variety	Planting date	Seed yield ha^{-1} (kg)			Earliness %	Min.	Max.	Difference from the min	Difference from the Max	Yield reduction	Yield red /1 °C min	% of the best planting date	Yield red /1 °C max	% of the best planting date	PTI (°C)	HUE
		80 days	100 days	Total												
V2010	D1 (15/5)	1643ab	1012 bc	2655b	0.62	17.0	27.0	-	-	-	-	-	-	-	23.2	2.65
	D2 (1/6)	1284 b	986 c	2270 b	0.57	19.5	31.5	2.5	4.5	384	154	5.8	85.4	3.2	26.0	2.06
	D3 (15/6)	882 c	606 d	1488 c	0.59	23	36.5	6.0	9.5	1166	195	7.3	122.7	4.6	30.5	1.23
	D4 (1/7)	941 c	512 e	1453 c	0.65	23.5	37.5	6.5	10.5	1201	185	7.0	114.4	4.3	29.0	1.16
	D5 (15/7)	718 d	648 d	1366 c	0.53	25.0	38.0	8.0	11.0	1289	161	6.0	171.7	6.5	32.5	1.13
Kawmy^{-1}	D1 (15/5)	1993 a	1722 a	3715 a	0.54	17.0	27.0	-	-	-	-	-	-	-	24.6	3.75
	D2 (1/6)	2070 a	1372 b	3442 a	0.60	19.5	31.5	2.5	4.5	273	109	3.2	162.8	3.7	27.6	3.13
	D3 (15/6)	1321 b	1014 b	2335 b	0.57	23.0	36.5	6.0	9.5	1380	230	6.7	145.3	4.2	31.4	1.93
	D4 (1/7)	977 c	1135 b	2112 b	0.46	23.5	37.5	6.5	10.5	1603	158	4.6	152.6	4.4	32.1	1.77
	D5 (15/7)	932 c	982 c	1914bc	0.49	25.0	38.0	8.0	11.0	1798	225	7.2	163.5	4.7	33.0	1.16

Heat Stress Indices

Growing degree days GDD (ºC day) presented in Table (5). Accumulated GDD for mungbean crop was 1000 units (90 days to physiological maturity), and the accumulated GDD or the other planting dates were 1100, 1210, 1250 and 1200 unites for D2, D3, D4 and D5, respectively. This explains the direct impact of temperature on crop growth, where every crop needs a certain amount of GDD to enter its next crop stage. Helio thermal unit (Degree-days hours HTU accumulated for mungbean during different planting dates were 9000, 10510, 11542, 12812 and 11756 units for D1, D2, D3, D4 and D5, respectively. Difference in accumulated pattern between planting dates expresses a specific feature of using actual bright sunshine hours in HTU. HTU is the product of GDD and actual bright sun shine hours and affects physiological stages of growth and maturity especially flowering. Photo-thermal unit (Degree-days hours PTU accumulated for mungbean in different planting dates were 16000, 17700, 19440, 20500 and 19800 units (80 days to physiological maturity for D1, D2, D3, D4 and D5, respectively (Table 5).

Table 5 : Heat stress indices, GDD, HTU, Photo-thermal unit PTU and relative temperature depression (RTD) in different planting dates of mungbean.

Planting date	Growing degree days (Degree days) GDD (°C day)	Helio thermal unit (Degree-days hours) HTU (°C day)	Photo-thermal unit PTU (°C day)	Relative Temperature Depression (RTD)
D1 (15/5)	1000	9000	16000	0.45
D2 (1/6)	1100	10510	17700	0.47
D3 (15/6)	1210	11542	19440	0.45
D4 (1/7)	1250	12812	20500	0.46
D5 (15/7)	1200	11756	19800	0.41

Regardless planting dates. Photo-thermal index (Degree-days day^{-1}) PTI for both varieties was similar and ranged between 23.2 to 32.5 °C for V2010 and 27.6 to 33 °C for Kawmy^{-1}. PTI gradually increased as planting dates retarded for both varieties. Also, PTI appeared gradual increments and ranged between 28.71 °C and 32.72 °C for the planting dates D2 - D5 compared with 23.92 °C for the best planting date D1. Heat use efficiency (Kg ha^{-1} degree days was calculated by using accumulated GDD and seed yield (Table 6). HUE was 1.65 kg seed ha^{-1} degree day^{-1} for V2010 and 2.44 kg seed ha^{-1} degree day^{-1} for Kawmy^{-1}. HUE showed lower values as planting dates retarded and such reductions were gradual from D2 to D5 compared with D1 the best planting date. However, effects of HTU and effect of using actual bright sunshine hours (HTUE) in helio thermal units prove evident of weather variations in the different planting dates.

Table 6: Heat stress indices PTI and HUE in different planting dates of mungbean.

Treatment		Photo-thermal index (Degree-days day^{-1}) PTI (°C)	Heat use efficiency (Kg ha^{-1} degree days) HUE
Variety	Planting date		
V2010	D1 (15/5)	23.20	2.65
	D2 (1/6)	26.00	2.06
	D3 (15/6)	30.47	1.23
	D4 (1/7)	28.98	1.16
	D5 (15/7)	32.48	1.13
Mean		28.23	1.65
Kawmy-1	D1 (15/5)	24.63	3.75
	D2 (1/6)	27.64	3.75
	D3 (15/6)	31.42	3.13
	D4 (1/7)	32.13	1.93
	D5 (15/7)	32.96	1.77
Mean		24.83	2.44
D1 (15/5)		23.92	3.20
D2 (1/6)		28.71	2.91
D3 (15/6)		30.94	2.18
D4 (1/7)		30.58	1.55
D5 (15/7)		32.72	1.45

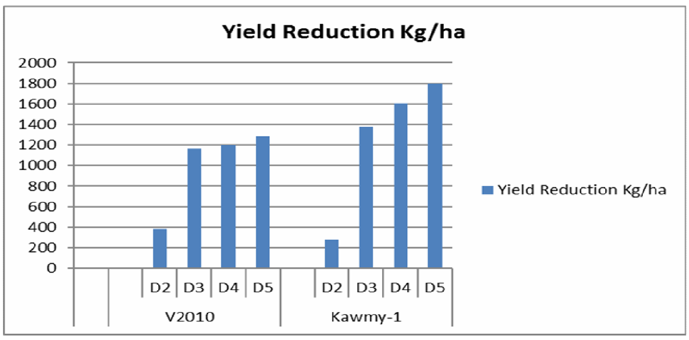

Fig. 2: Seed yield reduction of mungbean varieties relative to D1 planting date.

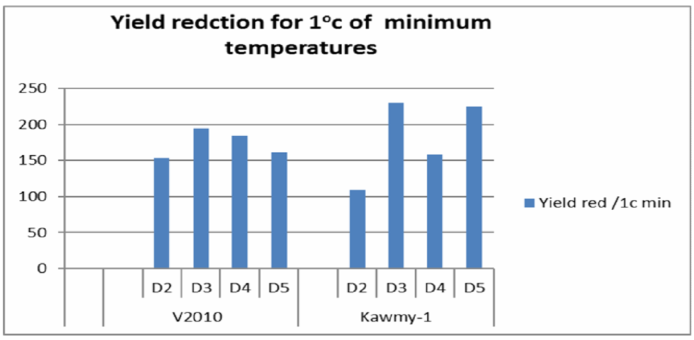

Fig. 3: Seed yield reduction of mungbean varieties increase in the minimum temperatures by 1°C over D1 planting date.

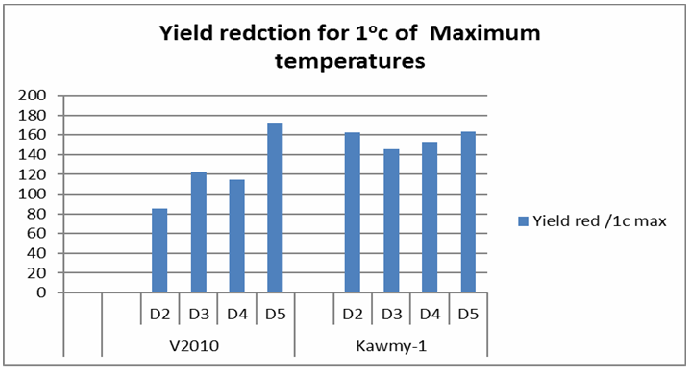

Fig. 4: Seed yield reduction of mungbean varieties increase in the maximum temperatures by 1ºC over D1 planting date.

Discussion

The obtained results about the varietal differences in their tolerance to heat stress regardless planting date indicated that Kawmy^{-1} flowered earlier and produced > 50% of seed yield plant^{-1} and seed yield ha^{-1} of the total seed yield at the 1st harvest (80 days after sowing) compared with V2010. These results are in harmony with those obtained by Abd El Lateef *et al.* (1998) found that different mungbean accessions gave their first flower after a period of 43 to 45 days and from 44.3 to 46.3 in two successive seasons in Egypt. Shalaby *et al.* (1991) found that different mungbean accessions gave their first flower after a period of 45 to 55 days and from 44.3 to 56.3 in two successive seasons in upper Egypt. Also, these results are in accordance with the results obtained by other researchers for most of the legumes (Mahmood-ul-Hassan *et al.*, 2003; Achakzai and Kayani 2004; Malik *et al.*, 2006 and Siddique *et al.*, 2006).

It is notable from the results of the effect of planting date that the planting date 15/5 (D1) gave the highest values concerning yield characters which reflected on the total seed yield ha^{-1} and surpassed D2, meanwhile the differences among D2 and D3, D4 and D5 in the total seed yield ha^{-1} were insignificant. In this respect Naveed *et al.* (2015) indicated that maximum plant height, pods per plant, pod length, seeds per pod, 1000 grain weight, seed yield belonged to June 2nd planting followed by May 26th while beyond this, there was a gradual decrease in yield and relevant components. The results indicated significant interactions between variety and planting date, seed yield reduction due to the increase in temperature as planting dates retarded from D2 to D5 and it was more pronounced for Kawmy^{-1} than V2010. Similar results on the interaction between variety and planting date were reported by Sarkar *et al.* (2004) they observed that early planted (03 and 18 February) mungbean produced higher yield as compared to late planted (05 and 20 March mungbean. Also, Miah *et al.* (2009) confirmed that there is interaction between variety and sowing date significantly influenced all the yield contributing characters (except 1000-seed weight) and yield of summer mungbean. Yield contributing characters like number of pods plant^{-1}, seeds pod^{-1} and seeds plant^{-1} contributed to the highest seed yield.

The pre mentioned results exhibited gradual increases in the mean minimum or maximum temperatures over D1 planting date as planting dates advanced. Seed yield reduction due to the increase in temperature as planting dates retarded from D2 to D5 and it was more pronounced for Kawmy-1 than V2010 indicating the greater sensitivity of Kawmy^{-1} to the increase in minimum or maximum temperature. These results confirm the sensitivity of Kawmy^{-1} to the increase either in minimum or maximum temperatures from D2 to D5 planting dates indicating the importance of planting it in the optimum date. The reduction in seed yield due to the high temperatures in the affected planting dates could be attributed to heat stress effects and The reduction in seed yield due to the high temperatures in the affected planting dates could be attributed to heat stress effects and it was reported that heat stress has a harmful effect at several levels of plant functions, leading to a drastic reduction in growth rates and yield traits (Wahid *et al.*, 2007). Photosynthetic mechanism in leaves is recognized sensitive to elevated temperatures. (Sinsawat *et al.*, 2004). Also, Reproductive tissues and their functions are highly sensitive to heat stress, and a few degrees raise in temperature during flowering can lead to loss of entire grain crop cycles (Wheeler *et al.*, 2000; Hatfield *et al.*, 2011 and Asseng *et al.*, 2011). Moreover, Naveed *et al.* (2015) indicated that optimum planting date is an important factor for achieving improved mungbean production in different agro-ecological zones of the world, They added that Maximum plant height, pods per plant, pod length, seeds per pod, 1000 grain weight, seed yield belonged to June 2nd planting followed by May 26th while beyond this, there was a gradual decrease in yield and relevant components.

The effects of elevated heat in the later planting dates was interpreted by similar work of Chikukura *et al.* (2017), they reported that elevated temperatures > 44/34 ºC significantly affected net photosynthesis at all stages. They also added that a departure from the normal seasonal temperatures by 8-10 ºC resulted in shortened phenological stages specifically vegetative phase leading to earlier maturity 50-57 DAS compared to the control that reached maturity between 70-77 DAS under normal summer seasonal temperature. The increase in temperature negatively reduced number of pods per plant as well as the test weight of mungbean. Heat Stress Indices revealed that the Accumulated GDD for mungbean increased for the planting dates D2, D3, D4 and then decreased at D5. This explains the direct impact of temperature on crop growth; every crop needs a certain amount of GDD to enter its next crop stage.

Heat unit concept was applied to correlate phenological development in crops to predict maturity dates (Rao *et al.*, 1999). Ram *et al.* (2012) reported higher GDD requirement for wheat crop for normal sowing conditions than the later growing conditions. Late sowing decreased the duration of phenology as compared to normal sowing due to fluctuated un-favorable high temperature during the growing period. The difference in accumulated pattern between planting dates expresses a specific feature of using actual bright sunshine hours in HTU. HTU is the product of GDD and actual bright sun shine hours and affects physiological stages of growth and maturity especially flowering.

Several studies in India have shown that a delay of 20 days in sowing could cause a delay in flowering by 8 days or up to 13 days. (Brar *et al.*, 2011). Generally, the obtained results on heat stress indices were similar to those obtained by Kumar (2017) who reported that, only HUE showed significant and positive association with SY indicating that their effective utilization for heat tolerance in green gram. Also, Kumar (2017) showed interrelationship among the different heat stress indices. They reported that heat use efficiency showed significant and positive association with seed yield. Days to maturity showed significant and positive association with growing degree days, helio thermal unit, photo thermal unit and relative temperature depression.

These results indicate that mungbean is among the most temperature sensitive crops and production could fluctuate with a slight change in temperature which could be observed from the lower yields exposed to heat stress in the later planting dates compared with the best planting date D1. Also, it seems that mungbean seed yield depends on the balance between photosynthesis and respiration therefore air temperature plays import role mungbean productivity. Relative temperature depression (RTD) do not exhibit clear tendency but there was a reduction in this index at the latest planting date D5.

It seems that there are relationship among heat stress indices where Growing degree days showed significant and positive association with helio thermal unit, photo thermal unit and relative temperature depression. Heat use efficiency showed significant and positive association with photo thermal unit and relative temperature depression whereas significant and negative association with photo and negative association with photo thermal index). Also, Photo thermal unit showed significant and positive association with relative temperature depression and significant and negative.

Conclusion

This study indicated that there were varietal differences in heat stress tolerance under the unfavorable planting dates of mungbean. Seed yield reduction due to the increase in temperature as planting dates retarded and it was more pronounced for Kawmy^{-1} than V2010 indicating the greater sensitivity of Kawmy-1 to the increase in minimum or maximum temperatures and the importance of planting it in the optimum date.

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