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ORIGINAL PAPER

EFFECT OF CLIMATE CHANGE ON MUNGBEAN GROWTH AND PRODUCTIVITY UNDER EGYPTIAN CONDITIONS

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Abstract

In order to study the proper heat regime as one of the most important factors for climate change, seeds of mungbean Kawmy-1 variety were exposed to variable extreme waves of temperatures (minimum - maximum °C) through sowing the seeds on six planting dates, viz: D1 (15 - 22 °C), D2 (18 - 26 °C), D3 (22 - 32 °C), D4 (28 - 38 °C), D5 (27 - 37 °C) and D6 (15 - 22 °C). Mungbean planted in the heat regimes of (18 - 26 °C), (22 - 36 °C) and (28 - 38 °C) could complete their life cycle and produced reasonable yield. Other heat regimes seem to be unfavorable for mungbean since either the seeds did not germinate (15 - 22 °C) or the growth was retarded and in turn no yield was obtained (15 - 22 °C). Mungbean plant sown in the heat regime of (22 - 32 °C) matured earlier, being taller, producing greater number of leaves and branches with heavier weight than that in the other heat regimes. The reduction in minimum temperature by one degree caused reductions in total dry matter plant^{-1} by 13 and 6% while increasing minimum temperature over the optimum sowing temperature by one degree caused reductions in total dry matter plant^{-1} by 12.4 and 19.6%. The reduction in minimum temperature by one degree in D2 (18 - 26 °C) caused reduction in seed yield ha^{-1} by 10.3 and 9.6% per plant and per hectare, respectively. While the reduction in maximum temperature by one degree in D2 (18 - 26 °C) caused reduction in seed yield ha^{-1} by 6.9 and 6.3 % per plant and per hectare, respectively. Meanwhile, increasing minimum and maximum temperatures by one degree in D4 (28 - 38 °C) caused reduction in seed yield ha^{-1} by 10.2 and 9.8% per plant and per hectare, respectively. It could be concluded from this study that heat regime is crucial for mungbean planting in Egypt. Mungbean proved to be very sensitive to fluctuations in minimum and maximum temperatures. The most favorable heat regime for mungbean production in Egypt is heat regime of (22 - 32 °C).

Keywords: Climate change, Mungbean, Minimum and maximum temperature, Yield

INTRODUCTION

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., 1993). During the last decades soybean was successfully introduced in Egypt. Mungbean or green gram (*Vigna radiata* (L.) Wilczek) in an early maturing high yielding pulse crop that widely spread and cultivated on > 6 million ha in the warmer regions of the world and is one of the most important pulse crops. It is a short duration (65 - 90 days) grain legume having wide adaptability and low input requirements (Nair et al., 2012). Cultivation of the crop extends across wide regime of latitudes (40 N or S) in regions with diurnal temperatures of growing season are > 20 °C (Lawn and Ahn, 1985). Mungbean has a distinct advantage of being short-duration and can grow in wide regime of soils and environments as mono or relay legume (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). Though it is considered as poor men's protein (Mian, 1976), productivity is very low in tropical and sub-tropical regions of Asia including many countries (Haider and Ahmed, 2014).

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Mungbean can be successfully grown in a wide regime of environments throughout the tropics and subtropics regions. Phoehlman (1991) through his observation of International Mungbean Series (IMN) reported that a 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.

Environmental stress is one of the limiting factors to producing crops. Although mungbean is a tropical crop and gives the best growth and seed yield in arid and semi-arid regions, heat limitation is undoubtedly a critical environmental constraint hampering the crop production. Climate change has negative consequences for sustainable development, undermining the gains of intensive farming in developing countries. In recent years, climate change has received a significant amount of attention included the impacts of the changes in temperature and rainfall patterns, water scarcity, natural disasters, and extreme weather events (Land Portal, 2018).

It was reported that heat stress has a 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. Photosynthesis may be inhibited as a result of loss of chlorophyll and reduced carbon fixation and assimilation (Sinsawat et al., 2004; Gezer, 2018). 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; Asseng et al., 2011). 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 evaluated the effects of different planting dates on the performance of mungbean cultivars under rainfed conditions, consisting of eight planting dates (May 26th, June 2nd, 9th, 16th, 23rd, 30th and July 7th, 14th) and two cultivars. They reported 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. Also, (Poehlman, 1991) indicated that the period of mungbean production required mean temperature of air and soil ranging from 20 to 30 ^{o}C. The trend of higher harvest indices to lower might be due to optimum regimes of both air and soil temperature and rainfall during the growth phases of crops especially in some planting dates which enhance assimilates production and transport into reproductive sink organ like grain. Chikukura et al. (2017) reported that elevated temperatures >44/34 °C significantly affected net photosynthesis at all stages. 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. Increase in temperature negatively reduced number of pods per plant as well as the test weight of mungbean.

Therefore the aim of current work is to find the impact of variable heat regimes on growth and yield of mungbean as a new crop under Egyptian conditions all around the year.

MATERIALS AND METHODS

In order to determine the proper heat regime for growing mungbean as a new crop under Egyptian conditions all around the year, field experiments were conducted in clay soil in Qalubia governorate. The chemical and mechanical analyses of the soil are presented in (Table 1).

Table 1. Chemical analysis of the experimental soil.

Mechanical Analysis	
Texture	Sandy Clay Loam
Sand	57.2 %
Silt	10.5 %
Clay	32.3 %
Ec	1.29 Mm hos/cm
Chemical Analysis	
Organic Matter	1.89 %
Calcium Carbonate	2.88 %
pH	7.73 %
Total N	0.08 %
Available P	13.6 PPM
Available Fe	19.32 ppm
Available Zn	2.53 ppm
Available Mn	15.20 ppm
Available Cu	3.54 ppm

To create variable extreme waves of temperatures mungbean seeds of the Kawmy-1 variety were sown at 6 dates every 2 months(Figure 1) namely, mid – February D1 (15 - 22 ^{o}C), mid-April D2 (18 - 26 ^{o}C), D3 mid-June (22 - 32 ^{o}C), mid-August D4 (28 - 38 ^{o}C), mid-October D5 (27 - 37 ^{o}C) and mid-December D6 (15 - 22 ^{o}C). The soil was ploughed twice, ridged and divided into experimental plots. The area of the plot was 21 m^2 and each contained 5 rows 6 meter long. Mungbean seeds were sown in hills 10 cm apart by the Afeer method (dry soil) at the experimented sowing dates. After complete germination, the plants were thinned and one healthy plant per hill was left to grow.

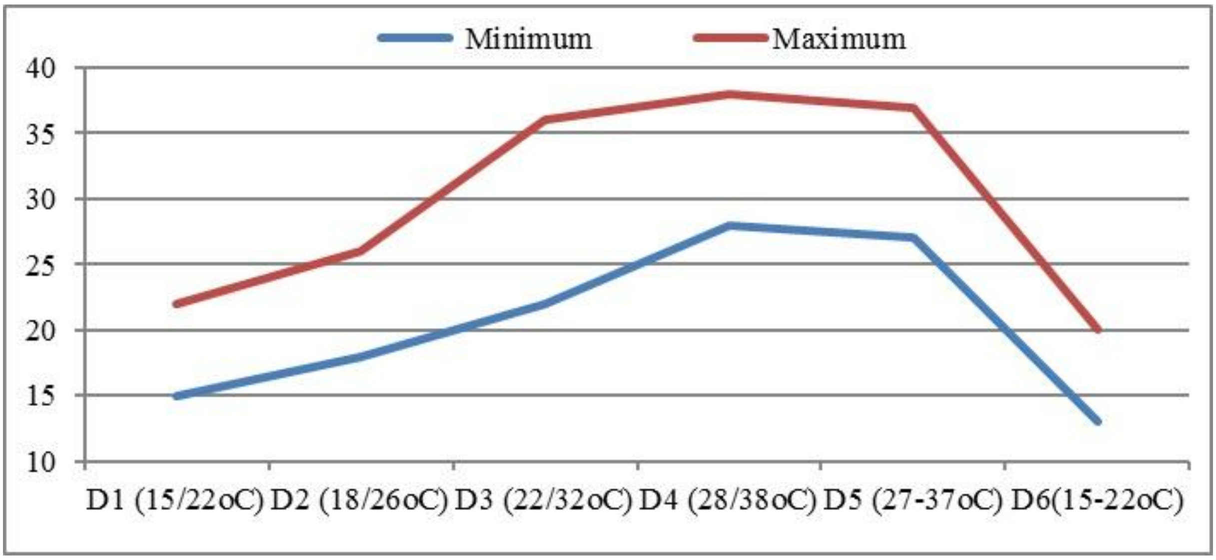

Figure 1. Minimum and maximum temperatures registered during selected sowing dates

During seed bed preparation, calcium super phosphate (15.5%) was applied at the rate of 37 kg P_20_5/ha. Before the 1st irrigation, nitrogen fertilizer as ammonium sulphate (20.6 % N) was applied at the rate of 72 kg nitrogen/ha. Irrigation was applied according to the recommended practice for irrigation in the district. The experimental plots were arranged in a Complete Randomized Block Design (CRBD) with 6 replicates; each 6 plots which assigned to a planting date was shown on the planned time, after 50 days from sowing, a vegetative sample was taken to determine:

(1)- Plant height. (2)- Number of leaves per plant.
(3)- Number of branches per plant. (4)- Dry weight of leaves per plant.
(5)- Dry weight of stems per plant. (6)- Total dry weight per plant.

Number of days to maturity was recorded for the plants which were able to complete their life cycle. A random sample of 10 plants from each plot was harvested to determine the yield components as follows:

1) Number of pods per plant.
2) Weight of pods per plant.
3) Seed yield per plant.
4) Seed index (1000 seeds weight).

Then the two central rows in each plot were harvested, dried, shelled to calculate seed yield per hectare.

In order to determine the actual reduction of dry matter or seed yields per plant and per hectare due to heat effect, the difference in optimum minimum and maximum temperature waves was calculated and the reduction in these criteria were determined relative to the optimum heat regime reported for 1^{o}C.

At certain heat regimes mungbean plants could complete their life cycle, while the others they could not complete the life cycle. Thus, the data were modified to be statistically analyzed according to the description of "problem data" by (Gomez and Gomez, 1984). For means comparison, Duncan multiple regime test at 5% level was applied.

RESULTS AND DISCUSSION

Growth

Firstly, it is worthy to mention that the mungbean seeds of mid-December planting D6 did not germinate. Data presented in (Table 2 and Figure 2) show that mungbean plants differed significantly in plant height according to the different planting dates. The shortest mungbean plants were obtained when the seeds were sown either in D1 (15 - 22 ^{o}C) or D5 (27 -37 ^{o}C). Whereas, a moderate plant height was found due to D4 (28 - 38 ^{o}C) planting. The tallest mungbean plants were obtained if the seeds were planted either in D2 (18 - 26 ^{o}C) or D3 (22 - 32 ^{o}C).

Table 2. Effect of heat regime on growth characters of mungbean at 50 days after sowing.

Temperature Min/Max	Plant height (cm)	No. of leaves / plant	No. of branches / plant	Dry matter weight		
				Leaves	Stem	Total
D1 (15-22°C)	11.3 c	2.0 c	0.0 d	2.8 d	2.5 d	5.3 d
D2 (18-26°C)	83.8 a	33.3 a	4.5 c	25.8 b	42.3 b	68.1 d
D3 (22-32°C)	85.5 a	49.9 a	6.5 a	35.0 a	55.0 a	90.0 a
D4 (28-38°C)	57.0 b	11.8 b	5.3 b	10.3 c	12.5 c	22.8 c
D5 (27-37°C)	10.1 c	5.0 c	0.0 d	1.0 d	11.8 cl	2.8 d

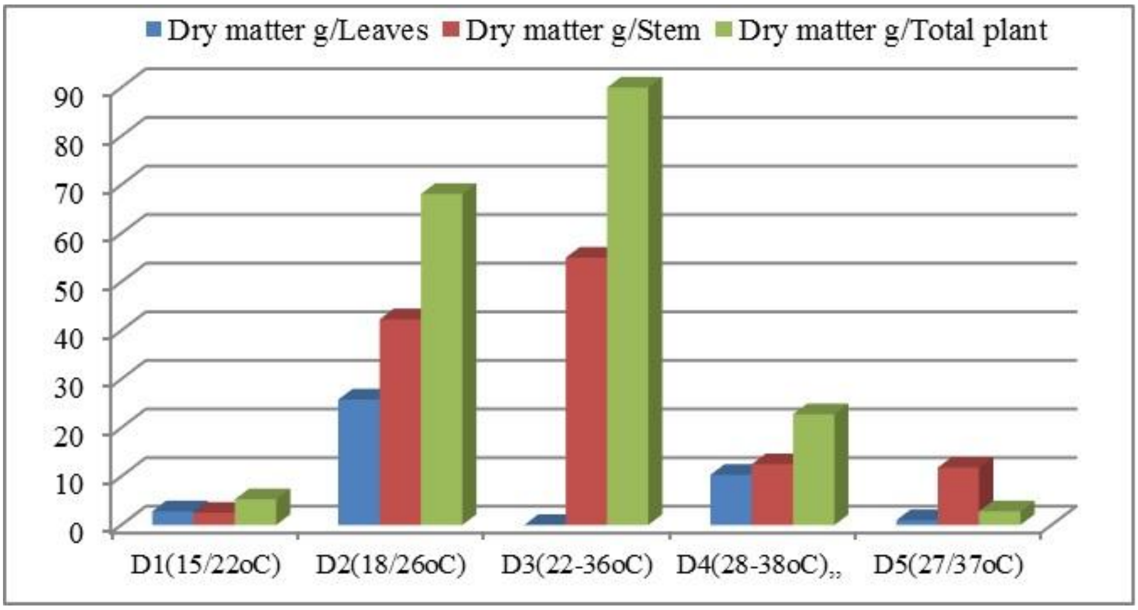

Figure 2: Effect of heat regime on mungbean dry matter accumulation (gm) at 55 days from sowing.

The same table also shows that the highest number of leaves per plant was recorded when planting was carried out either in D2 (18 - 26 °C) or D3 (22 - 32 °C). However, the differences in this character between the two planting dates were statistically insignificant. On the other hand, D1(15 - 22 °C) and D5 (27 - 37 °C) heat regimes induced the lowest number of leaves per plant.

Table (2), also shows that the mungbean plants planted in D3 (22 - 32 °C) produced the highest number of branches. On contrast, plants planted in either D1 (15 - 22 °C) or D5 (27 - 37 °C) failed to form any branches. (Table 2 and Figure 2) show the dry matter content of mungbean as affected by heat regime. The data clearly show that planting date significantly affected the dry matter accumulation by mungbean plants. The greatest dry matter content per plant was accumulated by mungbean plants planted in D3 (22 - 32 °C) followed by those planted in D2 (18 - 26 °C) and D4 (28 - 38 °C) in descending order.

The superiority in plant height; number of both leaves and branches may enable the plants to accumulate more dry matter. This trend was observed in the plantings of D2 (18 - 26 °C), D3 (22 - 32 °C) and D4 (28 - 38 °C), whereas, the reverse magnitude was found for plantings of D1(15 - 22 °C) and D5 (27 - 37 °C). The obtained results clearly indicate that the environmental factors in Egypt especially heat patterns may affect the growth of mungbean plants. Under Egyptian conditions, it seems that mungbean can be considered as a summer crop and can be sown in mid-June at heat regime (22 - 32 °C) to obtain the outmost vegetative growth. Similar results were obtained by Sarkar et al. (2004). Heat stress can have detrimental effects at several plant stages, leading to drastic reduction in growth and yield of crop plants (Bindumadhava et al., 2017; Wahid et al., 2007).

Yield

It is worthy to note that mungbean plants which were planted in mid-February, D1 (15 - 22 °C) and mid-October D5 (27 - 37 °C) gave a poor vegetative growth and failed to complete their life cycle and in turn no yield was obtained so the other three plantings are presented.

The obtained results with regard to the yield of mungbean plants as affected by heat regimes were parallel with those reported for vegetative growth, the best yield was obtained with the heat regime D3 (22 - 32 °C). Such results clearly indicate the importance of determining the proper heat regime for planting mungbean.

Data presented in (Table 3) indicate that days to maturity, yield and yield components of mungbean plants were significantly affected due to the different heat ranges tested. Mungbean planted in D3 (22 - 32 °C) matured about 8 -11 days earlier than that in other two heat regimes. In this respect, (Naveed et al., 2015) reported that maximum plant height, pods per plant, pod length, seeds per pod, 1000 grain weight, seed yield belonged to June 2*nd* planting followed by May 26*th* while beyond this, there was a gradual decrease in yield and relevant components. Planting of mungbean in D2 (18 - 26 °C), seems to be more suitable than that of D4 (28 - 38 °C) in this respect. The data in the same table indicate that the highest seed index was obtained from sowing mungbean in D3 (22 - 32 °C).

In this respect (Sharma et al., 2016) found that the pod set was reduced to a tune of 15 - 45% due to high temperatures > 40 °C. The reduction in total number of flowers appeared, to be more vital in affecting number of pods. Reduction in total number of flowers appeared, to be more vital in affecting number of pods than the pod set, though the latter has also contributed considerably towards yield reduction.

Table 3. Effect of heat regime on yield and yield components of mungbean.

Temperature Min/Max	Days to maturity	No. of pods/ plant	Dry weight g/plant	Seed yield g/plant	Seed index (g)	Yield kg/ha
D2 (18-26 °C)	94.0 b	58.5 b	21.5 b	12.4 b	4.2 b	1338 b
D3 (22-32 °C)	83.0 a	93.0 a	37.0 a	21.2 a	5.6 a	2172 a
D4 (28-38 °C)	91.0 b	35.8 c	14.0 c	8.1 c	4.0 b	882 c

Seed yield of mungbean per hectare and per plant were also affected due to the different heat regimes (Table 4) and (Figures 2 and 3). The most superior seed yield both per plant and per hectare was obtained when mungbean was planted D3 (22 - 32 °C) as compared with other heat regimes. Also, the data revealed that the productivity of mungbean either per plant or per hectare was significantly higher in D2 (18 - 26 °C) planting than in D4 (28 - 38 °C) one. Malaviarachchi et al. (2015) reported that mungbean exposed to elevated temperature stress (>8°C) at various stages had earliness in phenological events with reduced flowering and podding phase compared to the control.

Effect of heat regime on dry matter accumulation and yield characters.

Data presented in (Table 4) show that dry matter of mungbean plants reached the maximum vales during D3 (22 - 32 °C) and severely affected with increasing or decreasing the minimum or maximum temperature degrees than the optimum planting date. Generally, the reduction in minimum temperature by one degree caused reductions in total dry matter formation/plant by 13 and 6% while increasing minimum temperature over the optimum sowing temperature by one degree caused reductions in total dry matter/plant by 12.4 and 19.6%. Sharma et al. (2016) revealed that between the two sowings (normal and late season), reduction in biomass (above-ground) was minimal in normal-sown plants and it significantly decreased (2-76%) under late-sown conditions because of higher temperatures.

Table 4. Dry matter reduction (g) per plant and (%) compared to the optimum temperature.

Temperature Min/Max	Dry matter Red (g)	Red. g/1 °C Min	Red. g/1 °C Max	Red. %/1 °C Min	Red. %/1 °C Max
D1 (15-22 °C)	84.7	12.1	8.47	13	9.4
D2 (18-26 °C)	21.9	5.47	3.65	6.0	4.1
D3 (22-32 °C)	90.0	-	-	-	-
D4 (28-38 °C)	67.2	11.2-	11.2	12.4	12.4
D5 (27-37 °C)	88.2	17.64-	7.64	19.6	19.6

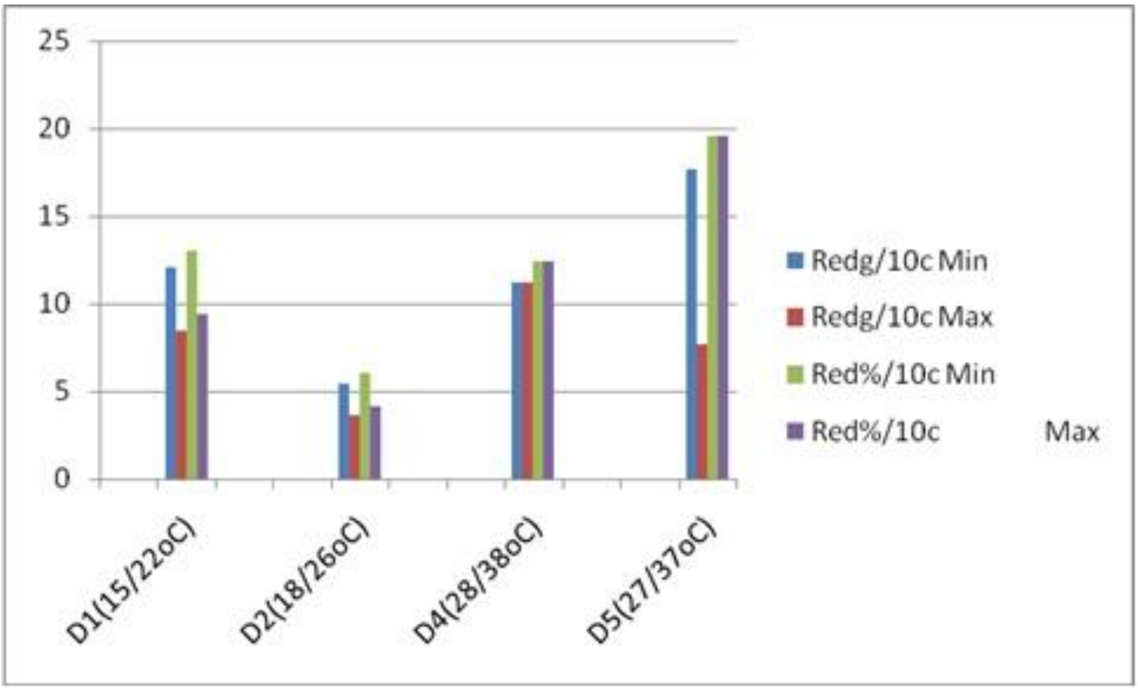

Figure 3. Seed yield reduction (g) per plant and (%) compared to the optimum planting temperature.

Table 5. Seed yield reduction (g) per plant and (%) compared to the optimum planting temperature.

Temperature	Yield	Red. g/1°C	Red. g/1°C	Red. % /1°C	Red. % /1°C
Min/Max	)g(	Min	Max	Min	Max
D2 (18-26°C)	12.Nis	2.2-	Oca.47	10.Mar	06.Eyl
D3 (22-32°C) Optimum	21.Şub	-	-	-	-
D4 (28-38°C)	08.Oca	Şub.18	Şub.18	10.Şub	10.Şub

Table 6. Yield reduction (kg) per hectare and (%) compared to the optimum planting regime.

Temperature Min/Max	Red. Kg/1 °C Max	Red. Kg/1 °C Min	Red. Kg/1 °C Max	Red. %/1 °C Min	Red. Kg/1 °C Max
D2 (18-26 °C)	834	208.5	139	09.Haz	06.Mar
D3 (22-32 °C) Optimum	2172	-	-	-	-
D4 (28-38 °C)	1290	215	215	09.Ağu	09.Ağu

Sharma et al. (2016) reported that late-sown mungbean plants showed severe reduction in biomass (up to 76%) and yield (up to 77%) as a result of the inhibition of vegetative growth, and acceleration of reproductive growth (both rate and period), apparently reducing flowering and pudding durations by 5 and 12 days, respectively. The reproductive stage is the most sensitive to rising temperatures, resulting in the loss of buds, flowers and pods that impact seed yield (Awasthi et al., 2014; Kaushal et al., 2013).

Data presented in (Table 5) show that seed yield of mungbean reached the maximum values during D3 heat regime and severely affected with increasing or decreasing the minimum or maximum temperature degrees than the optimum planting regime. The reduction in minimum temperature by one degree in D2 caused reduction in seed yield/ha by 10.3 and 9.6% per plant and per hectare, respectively. While The reduction in maximum temperature by one degree in D2 caused reduction in seed yield/ha by 6.9 and 6.3 % per plant and per hectare, respectively. Meanwhile, increasing minimum and maximum temperatures by one degree in D4 caused reduction in seed yield/ha by 10.2 and 9.8% per plant and per hectare, respectively. Heat stress has a detrimental effect at several levels of plant functions, leading to a drastic reduction in growth rates and yield traits (Wahid et al., 2007). Also, (Chikukura et al,. 2017)indicated that the net photosynthesis was significantly affected by heat stress at all stages of growth of mungbean and reduced by 14 - 20% at vegetative stage, 17- 21% at flowering stage and 16-30% at pod filling stage as compared to the control in both seasons and sowings.

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; Asseng et al., 2011). Kaur et al. (2015) stated that reproductive stage encompasses functioning of flowers to achieve pod set, which gets disrupted by heat stress, mainly due to loss of pollen viability, pollen germination, poor anther dehiscence, landing of pollen on stigma surface and subsequent germination through style. They attributed such reduction in yield components due to heat stress to its effect on the reproductive function especially the pod set, which regulates the number of pods and seeds, as the heat compromised their ability to fertilize ovules and caused flower abortion). The test weight (1000 seed) of mungbean was also affected by higher temperatures.

It was reported that during reproduction, a short period of heat stress can significantly reduce floral bud numbers and increase flower abortion, although variation in sensitivity within and among plant species and their lines exists (Li et al., 2013; Annisa et al., 2013). Chikukura et al. (2017) reported that high temperature stress (>44/34 ^{o}C) at pod filling phase led to the highest reduction in seed weight as ovules were not fully formed into mature seed.

The reduction in yield due to heat stress could be explained as HT stress induces changes in several cell metabolites, such as organic acids, amino acids, and carbohydrates, which play an important role in photosynthesis and respiration (Merewitz et al., 2012) and they are also involved in regulating vital metabolic functions within the plant, viz., water relations, signaling, protein synthesis, and stress defense (Yu et al., 2012; Zubayed et al., 2005).

CONCLUSION

It can be concluded that mungbean can be successfully grown under Egyptian conditions during the summer season. Heat regime is crucial for mungbean planting in Egypt. Mungbean proved to be very sensitive to fluctuations in minimum and maximum temperatures. The most favorable heat regime for mungbean production in Egypt is heat regime of (22 - 32 ^{o}C).

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