Vol. 22, No. 2, pp. 159-170 (2022)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Managing Climate Change Impacts on Growth and Yield of Maize by Adjusting Sowing Time

HARLEEN KAUR, P.K. KINGRA* AND SOMPAL SINGH

Punjab Agricultural University, Ludhiana-141004, Punjab

ABSTRACT

Maize production and productivity are highly prone to changes in weather conditions due to global warming related environmental alterations. Maize crop is particularly sensitive to temperature and water stress. High temperature and low rainfall are found to adversely affect maize yield. The present investigation was carried out to manage the effect of climatic variability in maize by adjusting sowing time. A field experiment was conducted at the Research Farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University Ludhiana during kharif 2016 and 2017 comprising three sowing environments (D_1: Third week of May, D_2: Second week of June, D_3: First week of July), two irrigation levels (I_1: Irrigation Water/Cumulative Pan Evaporation1.0, I_2: Irrigation water/Cumulative Pan Evaporation 0.75) and straw mulch application (M_1: mulch application @5t ha^{-1}, M_2: Without mulch). In the earlier sown crop, the maximum and minimum temperature was higher during initial and lower during later crop growth stages and the reverse pattern was observed with delay in sowing. As relative humidity is inversely proportional to temperature, thus relative humidity was lower during initial crop growth stages and increased at later stages of crop growth with delay in sowing. The crop received a total rainfall of 468.5 and 308.2 mm, 475.9 and 362.4mm and 282.3 and 258.0 mm under D_1, D_2 and D_3, during 2016 and 2017, respectively. Yield attributing characters *i.e.* number of grains per cob, length of cob and 1000-grain weights were higher under D_2followed by D_1 and D_3 during both the years. The highest grain yield was produced in D_2 (54.35 and 53.37 q ha^{-1}) which was statistically at par with D_1 (52.39 and 50.86 qha^{-1}) and was significantly higher than D_3 (44.48 and 41.04 q ha^{-1}) during both the years. The study concluded that sowing of maize during second week of June with mulch application and irrigation at IW/CPE = 0.75, provided best combination to increase the yield of maize crop.

Key words: Maize, Phenological stages, Weather parameter, Yield, Yield attributing characters

Introduction

Maize (*Zea mays* L.) plant is the one of the nature's most efficient and amazing energy storing devices. It is world's third major food crop after wheat and rice and is also called as "Queen of Cereals" due to its high productivity. India occupies fifth in area and eleventh place in production of maize in the world. In Punjab, it was grown on 144.6 thousand hectares area with a production of 410.5 thousand tonnes during 2020 (Anonymous, 2020). Presently while the developing countries have about 68 per cent area under maize cultivation, their contribution to world maize production is only 46 per cent. The maize crop has adapted well to the divergent climatic conditions prevailing in the tropical to temperate regions. Maize requires mean temperature of 18-20°C for good growth and yield. Maize production and productivity are prone to quick and continuous changes in weather conditions due

*Corresponding author,
Email: pkkingra@pau.edu

to global warming related environmental alterations. It is highly sensitive to temperature and water stress. High temperature and low rainfall are found to adversely affect the maize yield. Although, a C_4 plant, maize is capable of utilizing solar energy more efficiently and can withstand comparatively high temperature but temperature has detrimental effect on its growth and development leading to significant reduction in yield when it reaches up to 35°C during pollination and grain filling stages. Moreover, higher temperature (45 to 48°C at flowering and grain formation stages) is the most alarming factor that determines the crop growth and yield. It is estimated that for every 1°C increase in temperature, there is nearly 10% yield reduction in maize (Hatfield and Dold, 2018).

Maize crop is quite sensitive to the effects of climate anomalies. Thus, date of sowing is an important production component which can be altered to manage the adverse effects of environmental stress. This can be achieved by altering time of sowing to avoid environmental stresses during sensitive crop growth stages. Most appropriate sowing time can be chosen to coincide the sensitive crop growth stages with favourable environmental conditions to avoid stress and obtain maximum yield and resource use efficiency under changing climatic scenarios. Drought can cause considerable delays in maize female organ development (Barnabas *et al.,* 2008). During the reproductive stage, water shortage can also result in the inhibition of photosynthesis, thus also reducing the nutrient supply to generative organs. In addition, reduced soil moisture availability can further increase the likelihood of heat stress (Lobell *et al.*, 2013; Zampieri *et al.*, 2016).

Temperature and rainfall are the two important parameters, which affect crop growth and production. The past two decade have witnessed rapid increase in the awareness of global climatic changes and triggered widespread apprehension amongst scientists and governments about their implications (Kaur *et al.*, 2006). Global warming and climatic changes are expected to increase in future. Global circulation models have predicted rise in global average temperature by about 2°C by 2100 (Holli, 2010). Although total precipitation is also predicted to increase during kharif season, but trends may vary at local level (Hoegh-Guldberg *et al.,* 2018). Under such conditions, snow cover is expected to contract and frequency and intensity of extreme weather events like heat and cold waves, intense rainfall events etc. are likely to increase. There are evidences of increased heavy precipitation and decreased light precipitation in widespread parts of the globe due to global warming (Hoegh-Guldberg *et al.,* 2018). Due to highly erratic rainfall, there is an increased risk of drought as a result of increased prolonged dry spells, total dry days and decreased light precipitation days over India as a consequence of global warming (Kingra and Kaur, 2017).

Climatic changes have been experienced under Punjab conditions during the recent decades. The decadal analysis indicated that mean minimum temperature during kharif season, has increased at the rate of 0.044 °C per year in north-east regions, 0.051 °C per year in central region and 0.047 °C per year in south-west (Kingra *et al.*, 2017), although no significant trend was observed in maximum temperature and rainfall. In addition to this, depleting ground water table at alarming rates is posing a serious threat to water availability for agriculture (Hira, 2009). Maize crop can also be considered as good alternative to rice to diversify cropping pattern in the state. As Punjab state is already suffering from increasing temperature and depleting water resources, hence there is need to assess the weather variability effect on yield of maize crop to explore viable management strategies to manage climate change impacts and sustain crop productivity in the region. In view of this, the present investigation was conducted to assess meteorological parameters during various growth stages and evaluate maize productivity under different dates of sowing, irrigation levels and mulch application.

Materials and Methods

Site and climate

Ludhiana is situated at 30°54′ N latitude, 75°56′ E longitude and at an altitude of 247 meters above the sea level. The research farm, located in central plain region of Punjab, has semi-arid, sub-tropical climate with very hot summer during April-June and cold winter during December-January. The summer temperature touches 47°C with dry spells and winter experiences frost during December and January with minimum temperature reaching up to 0.5°C. The region is dominated by north-west winds during winter season. The average annual rainfall at Ludhiana is 733mm, 75-80 per cent of which is received during monsoon period from June to September. During winter, rains are scanty and only few showers of cyclonic rains are received by western disturbances.

Meteorological observations

The maximum and minimum temperatures during crop growing period were recorded with maximum and minimum thermometers installed in Stevenson's screen at 1.2 m height above the ground level. The data was recorded at 0730 and 1430 IST daily. Dry bulb and wet bulb temperatures were measured by dry and wet bulb thermometers installed in the Stevenson screen at 0730 and 1730 IST daily which were used to calculate morning and evening relative humidity from the hygrometric tables. The sunshine duration was recorded with a Campbell Stoke's sunshine recorder at 8.30 a.m. daily. The rainfall was recorded at the meteorological observatory with the help of ordinary rain gauge at 0830 IST daily.

Field experiment and crop biometric observations

The field experiment was conducted at the research farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana. Maize variety PMH1 was sown on three dates *i.e.,* third week of May (D1), second week of June (D2) and first week of July (D3) during kharif season 2016 and 2017. Yield attributing characters *viz.* number of grains per cob, cob length and 1000-grain weight were recorded at the time of threshing. Inner rows of each subplot were harvested by removing the two side rows, sun dried and threshed to record grain yield per plot. All the cobs from the respective net plot were dried in the sun and threshed with hand thresher and grain yield was recorded and expressed as kg ha^{-1}. Total biomass from each plot was recorded at the harvest of the crop and was converted to kg ha^{-1}. The harvest index was calculated by using the following formula:

$$\text{Harvest index (HI)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Biomass yield (kg ha}^{-1}\text{)}}$$

Results and Discussion

Variation in meteorological conditions during crop growth and development

Maximum temperature (°C)

Temperature is a variable used to calculate the thermal time that determines crop growth stages. During 2016, the mean maximum temperature from sowing to emergence, emergence to 5 leaf stage, 5 to 8 leaf stage, 8 to 12 leaf stage, 12 leaf to knee-high, knee-high to tasselling, tasselling to silking stage and silking to physiological maturity was 38.2, 39.3, 41.0, 37.7, 33.8, 34.1, 33.1 and 33.5 °C for D_1, 38.4, 37.4, 33.6, 34.8, 33.7, 33.1, 33.2 and 33.1 °C for D_2 and 34.5, 33.6, 34.4, 33.1, 33.0, 33.5, 33.1 and 34.5 °C for D_3 (Table 1). Similarly, during 2017, the mean maximum temperature for the corresponding stages was 40.2, 37.1, 41.7, 38.4, 35.7, 34.9, 33.4 and 34.4 °C for D_1, 38.5, 37.7, 35.4, 35.3, 34.7, 33.4, 34.4 and 32.7 °C for D_2 and 35.5, 35.2, 34.4, 32.8, 34.9, 34.1, 32.6 and 34.1 °C for D_3 (Table 2). The data indicated that under D_1, temperature was higher during initial growth stages and decreased towards maturity, whereas reverse pattern was observed with delay in sowing. It directly affects the crop growth rate and development. Increased temperature affects crop development by increased water requirement which reduces the economic yield (Wheelar, 2000).

Minimum temperature (°C)

During 2016, the mean minimum temperature from sowing to emergence, emergence to 5 leaf stage, 5 to 8 leaf stage, 8 to 12 leaf stage, 12 leaf to knee-high, knee-high to tasselling, tasselling to silking stage and silking to physiological maturity was 24.6, 25.0, 28.3, 28.8, 27.1, 27.8, 27.3 and 26.1 °C for D_1, 29.2, 28.4, 27.6, 27.7, 27.6, 27.2, 26.1 and 25.2 °C for D_2 and 27.2, 28.2, 27.2, 27.2, 27.0, 25.8, 25.3 and 25.8 °C for D_3 (Table 1). Similarly, during 2017,

Table 1. Variation in meteorological parameters during phenological development of maize sown on different dates during *kharif* 2016

Meteorological parameters	S-E	E - 5 Leaf	5 - 8 Leaf	8 -12 Leaf	12 Leaf -KH	KH - T	T- S	S-PM	S – PM
Third week of May									
T_{max} (ºC)	38.2	39.3	41.0	37.7	33.8	34.1	33.1	33.5	35.7
T_{min} (ºC)	24.6	25.0	28.3	28.8	27.1	27.8	27.3	26.1	27.2
RH_{max} (%)	63.4	60.6	55.7	72.6	77.4	85.1	82.1	86.0	75.9
RH_{min} (%)	30.9	26.0	27.3	52.2	66.1	62.5	66.3	65.4	54.3
SShr (hrs)	9.7	11.4	9.3	6.7	5.0	6.4	4.9	5.7	6.8
Rainfall (mm)	2.0	0.0	3.2	22.6	201.2	99.5	66.0	74.0	468.5
Second week of June									
T_{max} (ºC)	38.4	37.4	33.6	34.8	33.7	33.1	33.2	33.1	34.3
T_{min} (ºC)	29.2	28.4	27.6	27.7	27.6	27.2	26.1	25.2	27.1
RH_{max} (%)	68.9	74.2	77.1	83.4	85.1	82.1	85.6	87.2	81.8
RH_{min} (%)	44.8	57.3	68.0	59.6	65.4	65.1	66.5	63.7	62.4
SShr (hrs)	6.7	7.1	3.9	7.9	5.7	4.8	5.4	8.0	6.1
Rainfall (mm)	5.0	17.6	173.4	57.6	104.1	31.6	80.6	6.0	475.9
First week of July									
T_{max} (ºC)	34.5	33.6	34.4	33.1	33.0	33.5	33.1	34.5	33.7
T_{min} (ºC)	27.2	28.2	27.2	27.2	27.0	25.8	25.3	25.8	26.5
RH_{max} (%)	82.3	85.4	85.2	83.0	82.8	85.8	87.2	85.1	84.8
RH_{min} (%)	62.7	63.4	60.7	67.4	64.8	66.3	63.8	53.8	62.6
SShr (hrs)	6.8	5.8	7.7	5.3	4.3	5.9	7.9	8.2	6.6
Rainfall (mm)	57.6	27.5	42.2	66.0	8.0	72.6	6.0	2.4	282.3

S = Sowing, E = emergence, KH = Knee-High stage, T = Tasselling stage, S = Silking stage, PM = Physiological maturity

the mean minimum temperature for the corresponding stages was 26.0, 25.0, 27.9, 28.6, 27.2, 28.1, 27.6 and 27.4 °C for D_1, 28.7, 28.8, 27.9, 27.1, 28.2, 27.6, 27.4 and 25.5 °C for D_2 and 25.2, 28.3, 28.2, 27.5, 28.0, 27.1, 25.1 and 24.6 °C for D_3 (Table 2). The minimum temperature during second date of sowing proved to be favourable for growth and yield of maize crop.

Morning relative humidity (%)

During 2016, mean morning relative humidity from sowing to emergence, emergence to 5 leaf stage, 5 to 8 leaf stage, 8 to 12 leaf stage, 12 leaf to knee-high, knee-high to tasselling, tasselling to silking stage and silking to physiological maturity was 63.4, 60.6, 55.7, 72.6, 77.4, 85.1, 82.1 and 86.0% for D_1, 68.9, 74.2, 77.1, 83.4, 85.1, 82.1, 85.6 and 87.2% for D_2 and 82.3, 85.4, 85.2, 83.0, 82.8, 85.8, 87.2 and 85.1% for D_3 (Table 1). Similarly, during 2017, mean morning relative humidity for corresponding stags was 51.0, 58.4, 57.8, 63.1, 77.0, 77.9, 81.9 and 81.5% for D_1, 56.0, 72.0, 80.0, 77.0, 78.0, 82.0, 82.0 and 86.0% for D_2 and 80.0, 75.0, 80.0, 83.0, 81.0, 81.0, 87.0 and 85.0 % for D_3 (Table 2). The mean morning relative humidity for the entire growth period during 2016 and 2017 was 75.9 and 72.3%, 81.8 and 78.3% and 84.8 and 82.1% for D_1, D_2 and D_3, respectively (Figs. 1, 2 & 3). As relative humidity is inversely proportional to temperature, thus under first date of sowing, relative humidity was lower during initial crop growth stages and higher at later stages of crop growth whereas with delay in sowing, relative humidity increased during initial crop growth stages and decreased at later stages of crop growth.

Table 2. Variation in meteorological parameters during phenological development of maize sown on different dates during *kharif* 2017

Meteorological parameters	S-E	E - 5 Leaf	5 - 8 Leaf	8 -12 Leaf	12 Leaf -KH	KH - T	T- S	S-PM	S – PM
				Third week of May					
T_{max} (ºC)	40.2	37.1	41.7	38.4	35.7	34.9	33.4	34.4	36.3
T_{min} (ºC)	26.0	25.0	27.9	28.6	27.2	28.1	27.6	27.4	27.6
RH_{max} (%)	51.0	58.4	57.8	63.1	77.0	77.9	81.9	81.5	72.3
RH_{min} (%)	26.0	39.2	30.3	41.1	62.2	59.0	68.3	64.7	53.4
SShr (hrs)	10.4	10.5	9.0	9.7	6.2	7.3	4.7	7.1	7.6
Rainfall (mm)	0.0	21.6	26.6	23.8	116.8	72.2	20.6	26.6	308.2
				Second week of June					
T_{max} (ºC)	38.5	37.7	35.4	35.3	34.7	33.4	34.4	32.7	34.8
T_{min} (ºC)	28.7	28.8	27.9	27.1	28.2	27.6	27.4	25.5	27.5
RH_{max} (%)	56.0	72.0	80.0	77.0	78.0	82.0	82.0	86.0	78.3
RH_{min} (%)	32.0	52.0	66.0	59.0	59.0	68.0	65.0	67.0	60.7
SShr (hrs)	9.4	9.2	5.4	7.3	6.9	4.7	7.1	6.7	6.9
Rainfall (mm)	5.0	18.8	96.6	30.0	62.4	20.6	26.6	102.4	362.4
				First week of July					
T_{max} (ºC)	35.5	35.2	34.4	32.8	34.9	34.1	32.6	34.1	34.0
T_{min} (ºC)	25.2	28.3	28.2	27.5	28.0	27.1	25.1	24.6	26.6
RH_{max} (%)	80.0	75.0	80.0	83.0	81.0	81.0	87.0	85.0	82.1
RH_{min} (%)	59.0	59.0	60.0	69.0	66.0	65.0	67.0	54.0	62.6
SShr (hrs)	8.4	7.5	6.1	4.9	5.4	7.3	7.2	8.6	6.9
Rainfall (mm)	36.2	9.8	62.4	20.6	0.0	26.6	102.4	0.0	258.0

S = Sowing E = emergence, KH = Knee-High stage, T = Tasselling stage, S = Silking stage, PM = Physiological maturity

Evening relative humidity (%)

During 2016, mean evening relative humidity from sowing to emergence, emergence to 5 leaf stage, 5 to 8 leaf stage, 8 to 12 leaf stage, 12 leaf to knee-high, knee-high to tasselling, tasselling to silking stage and silking to physiological maturity was 30.9, 26.0, 27.3, 52.2, 66.1, 62.5, 66.3 and 65.4% for D_1, 44.8, 57.3, 68.0, 59.6, 65.4, 65.1, 66.5 and 63.7% for D_2 and 62.7, 63.4, 60.7, 67.4, 64.866.3, 63.8 and 53.8% for D_3. Similarly, during 2017, mean evening relative humidity for corresponding stags was 26.0, 39.2, 30.3, 41.1, 62.2, 59.0, 68.3 and 64.7% for D_1, 32.0, 52.0, 66.0, 59.0, 59.0, 68.0, 65.0 and 67.0% for D_2 and 59.0, 59.0, 60.0, 69.0, 66.0, 65.0, 67.0 and 54.0% for D_3. The mean evening relative humidity for the entire growth period during 2016 and 2017 was 54.3 and 53.4%, 62.4 and 60.7% and 62.6 and 62.6% for D_1, D_2 and D_3, respectively (Figs. 1, 2 & 3). The moderate moisture conditions under second date of sowing proved to be most favourable for growth and yield of maize crop.

Sunshine hours (hrs)

Solar radiation is an essential variable for crop growth, and it is often represented by sunshine hours (SSH) in agriculture studies. During 2016, the mean number of bright sunshine hours (hrs) from sowing to emergence, emergence to 5 leaf stage, 5 to 8 leaf stage, 8 to 12 leaf stage, 12 leaf stage to knee-high, knee-high to tasselling, tasselling to silking stage and silking to physiological maturity stage was 9.7, 11.4, 9.3, 6.7, 5.0, 6.4, 4.9 and 5.7 hrs for D_1, 6.7, 7.1, 3.9, 7.9, 5.7, 4.8, 5.4 and 8.0 hrs for D_2 and 6.8, 5.8, 7.7, 5.3, 4.3, 5.9, 7.9 and 8.2 hrs for D_3 (Table 1).

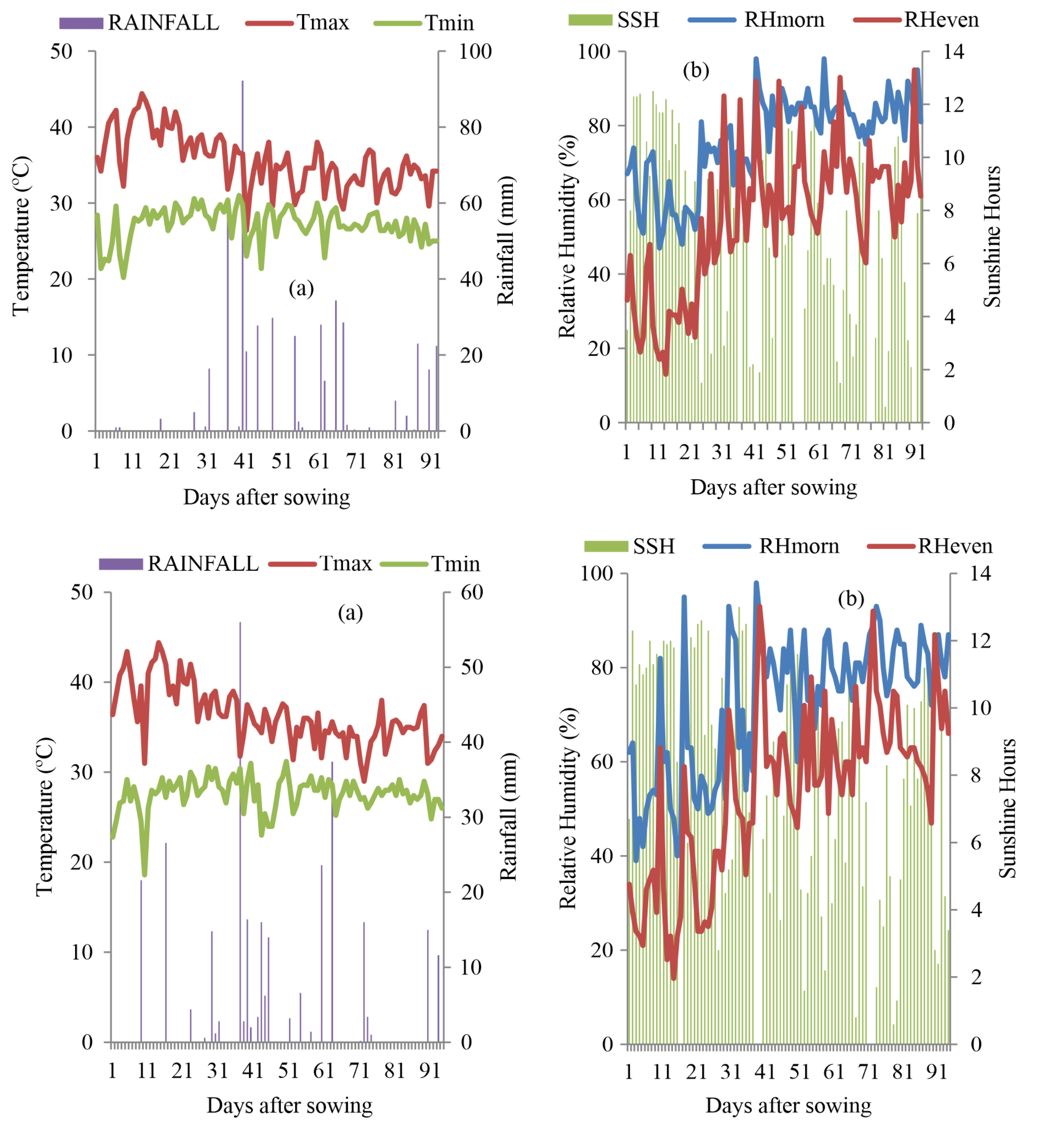

Fig. 1. Daily variation in (a) temperature and rainfall and (b) relative humidity and sunshine hours during growing season of maize sown on third week of May during *kharif* 2016 and 2017

Similarly, during 2017, the mean number of bright sunshine hours (hrs) for corresponding stages was 10.4, 10.5, 9.0, 9.7, 6.2, 7.3, 4.7 and 7.1 hrs for D_1, 8.4, 7.5, 6.1, 4.9, 5.4, 7.3, 7.2 and 8.6 hrs for D_2 and 8.4, 7.5, 6.1, 4.9, 5.4, 7.3, 7.2 and 8.6 hrs for D_3 (Table 2). The mean number of bright sunshine hours was maximum at emergence – 5 leaf stage (11.4 and 10.5 hrs) for both the seasons under D_1. Under D_2 it was maximum at silking – physiological maturity (8.0 hrs) during 2016 and at sowing- emergence (9.4 hrs) during 2017, respectively. Under D_3 it was maximum at silking – physiological maturity (8.2 and 8.6 hrs) for both the seasons, respectively (Figs. 1, 2 & 3). The sunshine hours was declined with delay

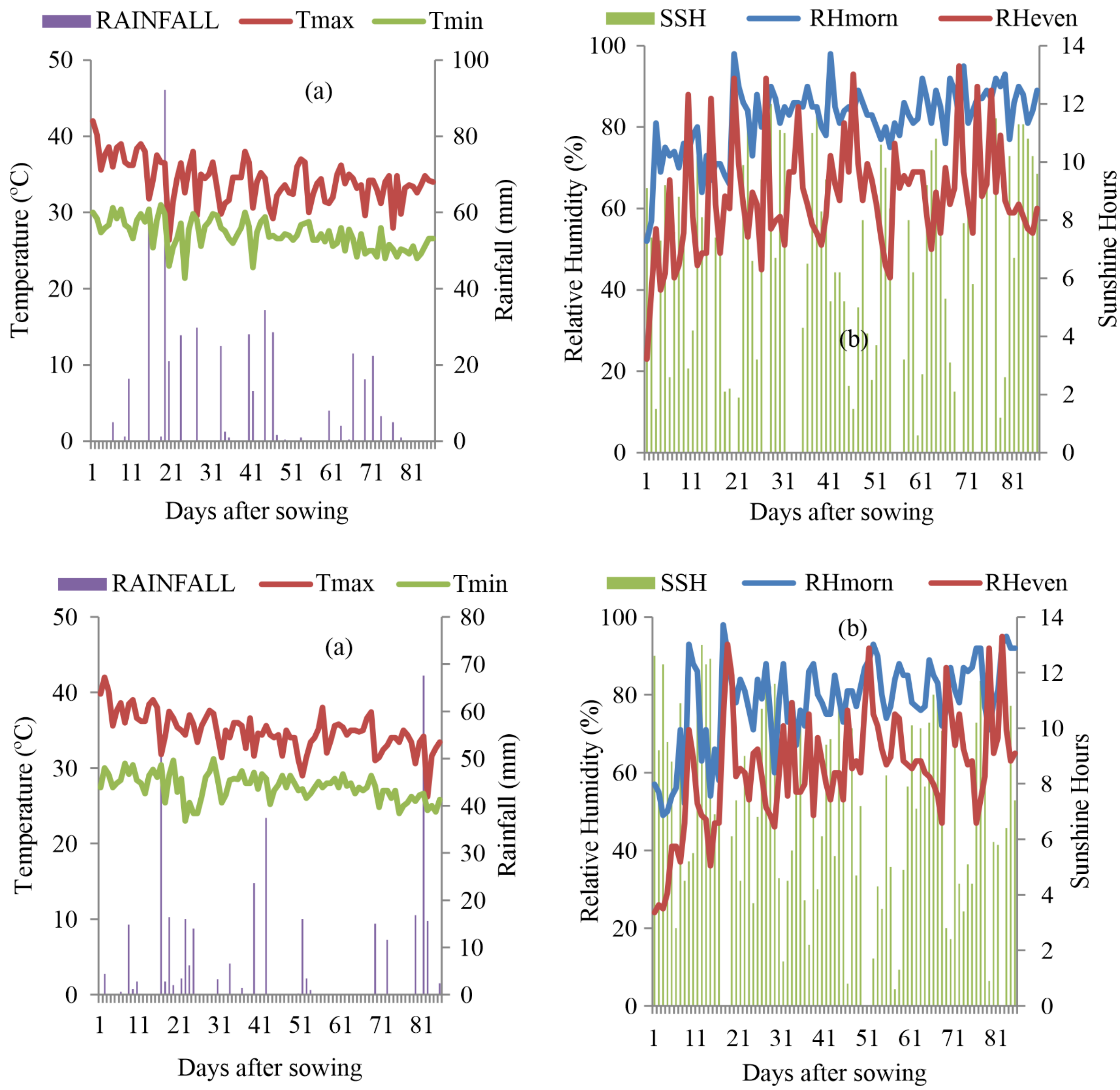

Fig. 2. Daily variation in (a) temperature and rainfall and (b) relative humidity and sunshine hours during growing season of maize sown on second week of June during *kharif* 2016 and 2017

in sowing. The decline in solar radiation could have reducedcrop photosynthesis and affect production (Song and Jin, 2020).

Rainfall (mm)

During 2016 and 2017, the total rainfall (mm) received for the entire crop growth was 468.5 and 308.2 mm, 475.9 and 362.4 mm and 282.3 and 258.0 mm, for D_1, D_2 and D_3 respectively. During 2016, the maximum amount of rainfall received at 12 leaf-knee high stage was 201.2 and 104.1 mm under D_1 and D_2, respectively. Under D_3 it was maximum at knee-high- tasselling stage *i.e.*72.6 mm. During 2017, maximum amount of rainfall received at 12 leaf- knee high stage, silking-physiological maturity and tasselling- silking stage was 116.8, 102.4 and 102.4 mm under D_1, D_2 and D_3, respectively (Table 1 & 2). Akpalu *et al*. (2011) showed that a change in rainfall amount is the primary driver of maize yields. The rainfall distribution can have an influence on maize yields regardless of the total seasonal rainfall. The climate change could alter the total amount of rainfall received in an area, which may be higher or lower in future scenarios, known as seasonal variability.

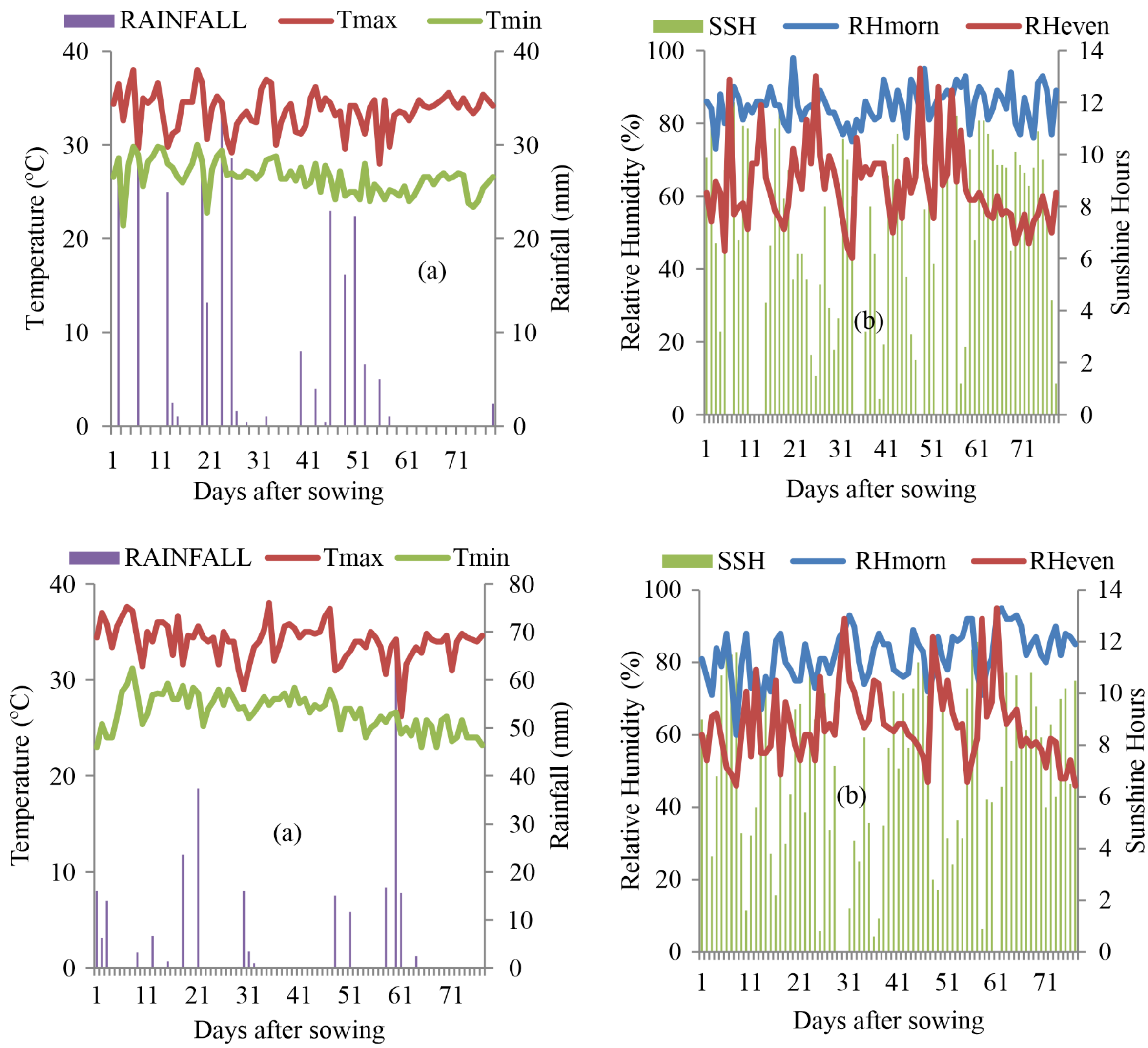

Fig. 3. Daily variation in (a) temperature and rainfall and (b) relative humidity and sunshine hours during growing season of maize sown on first week of July during *kharif* 2016 and 2017

Yield attributing characters

Number of grains per cob

The cob bearing capacity is one of the most important crop yield components. The analysis of data showed that the number of grains per cob was significantly affected by the sowing dates. The number of grains per cob under D_2 (393.45) was statistically at par with that of D_1(395.09) and it was significantly lower in D_3 (336.13). During 2017, the number of grains per cob under D_2 (377.57) was significantly higher than that of D_3 (332.90) and statistically at par with D_1 (373.56). Among the irrigation levels, the number of grains per cob were higher in I_2 (382.93 and 363.55) but it was statistically at par I_1 (366.93 and 359.14) irrigation treatment. Between the mulching levels, number of grains per cob were more in M_1 (380.97 and 363.73) as compared to M_2 (368.81 and 358.96) but the effect of mulching was non-significant on the number of grains per cob during 2016 and 2017, respectively (Table 3).

Cob length (cm)

During 2016,data showed that the cob length was significantly higher in crop sown on second week of June (19.9 cm) followed by third week of May (18.4 cm) and first week of July (17.6 cm). During 2017,

Table 3. Yield attributing characters of maize under different dates of sowing, irrigation and mulch levels during *kharif* 2016 and 2017

Treatment	Yield attributing characters					
	Number of grains per cob (g/m^2)		Length of cob (cm)		1000 grain weight (g)	
	2016	2017	2016	2017	2016	2017
Dates of sowing						
D_1 (Third week of May)	393.45	373.56	18.40	17.20	380.55	347.16
D_2 (Second week of June)	395.09	377.57	19.88	16.75	419.18	355.83
D_3 (First week of July)	336.13	332.90	17.56	14.89	375.84	337.08
CD (p=0.05)	30.15	12.38	0.56	1.34	20.86	NS
Irrigation levels						
I_1 (IW/CPE=1.00)	366.92	363.55	18.13	15.87	394.31	352.33
I_2 (IW/CPE=0.75)	382.85	359.14	19.10	16.69	389.41	341.05
CD (p=0.05)	14.27	NS	0.79	0.45	NS	NS
Mulch levels						
M_1 (with straw mulch @ 5t/ha)	380.97	363.74	18.78	16.62	405.74	349.33
M_2 (without mulch)	368.81	358.96	18.45	15.94	377.97	344.06
CD (p=0.05)	NS	NS	NS	0.45	19.27	NS

the cob length was significantly higher under crop sown on third week of May (17.2 cm) followed by first week of July (14.9 cm) but statistically at par with second week of June (16.8cm). Among irrigation treatments, the cob length was significantly higher in I_2 (19.1 cm and 16.7 cm) than I_1 (18.1 cm and 15.9 cm). Similarly, the cob length was higher in mulch treatment as compared to non-mulch treatment but the mulch application had no significant effect on the cob length during both the years (Table 3).

Singh and Singh (2000) also found increased cob length at higher moisture regimes as compared to moderate moisture regimes which in turn recorded higher cob length than the lower moisture regimes. Jaliya *et al.* (2008) studied the effect of sowing date (10, 20 and 30 June) on yield and yield components of maize (*Zea mays L.*) at Nigeria and found that sowing on 30th June produced significantly lower number of grains per cob, cob yield per plant, cob yield per ha, 100-grain weight, grain yield per plant and grain yield per ha than the earlier sown crop.

1000 grain weight (g)

The analysis of data showed that the 1000-grain weight was significantly affected by the sowing dates. The 1000-grain weight was significantly higher in the crop sown on second week of June (419.2 g and 355.8 g) followed by third week of May (380.6 g and 347.2 g) and first week of July (375.8 g and 337.1 g), during 2016 and 2017, respectively. During 2016, among the irrigation levels, 1000-grain weight was higher in I_1 irrigation treatment (394.3 g) than I_2 (389.4 g) but no significant effects was observed in these irrigation treatments. Among the mulch treatments, the 1000-grain weight was significantly higher in M_1 (405.7 g) as compared to M_2 (377.9 g). During 2017, among the irrigation treatments, 1000-grain weight was higher in case of I_2 irrigation treatment as compared to I_1. But irrigation and mulch did not show any significant effect (Table 3).

Namakka *et al.* (2008) in a study to find effect of sowing dates (end of June, mid-July and end of July) on maize at Nigeria revealed that maize sown in the end of June had the highest cob length, cob diameter and cob weight and grain yield as compared to late sown crops. Shinde *et al.* (2014) found that the plant height, dry matter production per plant and 1000-grain weight increased significantly when irrigation scheduled at 0.75 IW/CPE ratio compared with irrigation at critical growth stages. Jasemi *et al.* (2013) carried out a field experiment on maize at

Iran during 2010-2011 under three sowing dates (May 14, May 22 and July 13) and showed that sowing date had significant effect on grain yield, number of kernels per row, number of kernels per ear, 1000-grain weight, biomass, harvest index and plant height. The highest grain yield obtained was 11654 kg ha^{-1} on May 22.

Yield and harvest index

Biological yield

During 2016 and 2017, the biological yield (q/ha) was higher in D_2 (206.75 and 178.09 q/ha) as compared to D_1 (204.91 and 153.81 q/ha) and D_3 (182.46 and 146.90 q/ha), respectively, although difference was non-significant. The effect of different irrigation levels and mulch levels on the biological yield was found to be non-significant (Table 4).

Straw yield

During 2016, the effect of date of sowings, irrigation treatments and mulch levels wasfound to be non-significant. However, during 2017, significantly higher straw yield was produced when crop was sown on second week of June (124.72 q/ha) as compared to first week of July (105.86 q/ha) and third week of May (102.94 q/ha). The effect of irrigation levels and application of mulch was not significant (Table 4).

Grain yield

The date of sowing, irrigation and mulch application did not show any significant effect on grain yield, although grain yield was found to be the highest in D_2(54.35 and 53.37 q/ha) followed D_1 (52.39 and 50.86 q/ha) and D_3 (44.48 and 41.04q/ha), during both the years, respectively. Among the irrigation treatments, the difference in grain yield was found to be non-significant with higher grain yield recorded in I_2 (49.79 q/ha) as compared to I_1 (47.05 q/ha). Among the mulch treatments, the grain yield was found to be significantly higher in mulched treatment (M_1) (50.71q/ha) as compared to non-mulched treatment (M_2) (46.14 q/ha) during 2017, whereas the difference was non-significant during 2016 (Table 4).

Khan *et al.* (1996) found maximum grain yield of maize with irrigation level of 0.75 IW/CPE ratio (I_2) which was at par with that of 1.0 IW/CPE ratio (I_3). The highest grain yield (q ha^{-1}) was reported with 0.75 IW: CPE ratio (I_2) as compared to0.50 IW/CPE ratio (I_1) and this reduction in grain yield might

Table 4. Yield and harvest index of maize under different dates of sowing, irrigation and mulch levels during *kharif* 2016 and 2017

Treatment	Yield and Harvest Index							
	Biological yield (q/ha)		Grain Yield (q/ha)		Straw yield (q/ha)		Harvest index	
	2016	2017	2016	2017	2016	2017	2016	2017
Dates of sowing								
D_1 (Third week of May)	206.75	153.81	52.39	50.86	152.50	102.94	0.26	0.34
D_2 (Second week of June)	208.75	178.09	54.35	53.37	154.40	124.72	0.25	0.31
D_3 (First week of July)	182.46	146.90	44.48	41.04	137.98	105.86	0.24	0.30
CD (p=0.05)	NS	13.29	NS	5.22	NS	16.95	NS	NS
Irrigation levels								
I_1 (IW/CPE=1.00)	198.03	150.31	50.06	47.05	147.27	103.26	0.25	0.31
I_2 (IW/CPE=0.75)	198.03	168.88	50.75	49.79	147.98	119.09	0.25	0.32
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Mulch levels								
M_1 (with straw mulch @ 5t/ha)	199.16	161.27	51.92	50.71	150.27	111.56	0.26	0.33
M_2 (without mulch)	196.91	157.93	48.89	46.14	144.99	109.79	0.24	0.30
CD (p=0.05)	NS	NS	NS	3.5	NS	NS	NS	NS

be due to water deficit causing reduction in number of grains per cob and 1000-grain weight (Varughese and Iruthayaraj, 1996). Tariq *et al.* (2003) also found that maximum yield was obtained when plots were irrigated according to 0.75 pan evaporation.

Harvest index

The harvest index was not significantly affected by sowing dates. Higher harvest index was obtained when the crop was sown in third week of May (0.26 and 0.34) followed by second week of June (0.25 and 0.31) and first week of July (0.24 and 0.30) during 2016 and 2017, respectively. Harvest index was statistically at par under different irrigation levels and mulch application (Table 4).

Conclusions

The study concluded that sowing during second week of June with mulch application and irrigation at IW/CPE = 0.75 can be an effective practice to manage the effects of climate change on growth and yield of maize under Punjab conditions. However, more management strategies need to be explored to manage climatic risks on maize productivity in the region. In addition to this there is a dire need to develop early maturing and less water consuming cultivars to adapt the changing climatic conditions and sustain productivity.

References

Anonymous. 2020. Area and production of maize in Punjab and India. www.indiastat.com.

Barnabas, B., Jager, K. and Feher, A. 2008. The effect of drought and heat stress on reproductive processes in cereals. *Plant, Cell and Environment* **31**: 11–38.

Duffy, K.J. and Masere, T.P. 2015. Effect of within season daily rainfall distribution on maize crop yields. *Outlook on Agriculture* **44**(4): 267-271.

Hatfield., J.L. and Dold., C. 2018. *Climate change impacts on corn phenology and productivity*. pp. 95-114.

Hira, G.S. 2009. Water management in northern states and the food security of India. *J. Crop Improvement* **23**: 136-57.

Hoegh-Guldberg, O.D. Jacob, M. Taylor, M. Bindi, S. Brown, I. Camilloni, A. Diedhiou, R. Djalante, K.L. Ebi, F. Engelbrecht, J. Guiot, Y. Hijioka, S. Mehrotra, A. Payne, S.I. Seneviratne, A. Thomas, R. Warren, and Zhou, G. 2018Impacts of 1.5ºC Global Warming on Natural and Human Systems. *An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp.175-312.

Holli Riebeek. 2010. GlobalWarming. https://earthobservatory.nasa.gov/features/GlobalWarming

Jaliya, M.M., Falaki, A.M., Mahmud, M. and Sani, Y.A. 2008. Effect of sowing date and npk fertilizer rate on yield and yield components of quality protein maize (*Zea mays L.*). *ARPN J. Agric. Biol. Sci.* **3**(2): 23-29.

Jasemi, M., Darabi, F. and Naseri, R. 2013. Effect of planting date and nitrogen fertilizer application on grain yield and yield components in maize (SC 704). *American-Eurasian J. Agric. Environ. Sci.* **13**(7): 914-19.

Khan, G.M., Dand, G.M., Shah, M.H., Bali, A.S. and Singh, K.N. 1996. Response of intercropping system involving maize (*Zea mays* L.) irrigation levels in Kashmir valley. *Ind. J. Agric. Sci.* **66**: 272-75.

Kingra, P.K., Setia, R., Singh, S., Kaur, J., Kaur, S., Singh, S.P., Kukal, S.S. and Pateriya, B. 2017. Climatic variability and its characterisation over Punjab, India. *J. Agromet.* **19**(3): 246-250.

Kingra, P.K. and Kaur, H. 2017. Microclimatic modifications to manage extreme weather vulnerability and climatic risks in crop production. *Jour. Agric. Physics*. **17**: 1-15.

Lobell, D.B., Hammer, G.L., McLean, G., Messina, C., Roberts, M.J. and Schlenker, W. 2013. The critical role of extreme heat for maize production in the United States. *Nature Climate Change* **3**: 497–501.

Namakka, A., Abubakar, I.U., Sadik, I.A., Sharifi, A.I. and Hassas, A.H. 2008. Effect of sowing date and nitrogen level on yield and yield components of two extra early maize varieties (*Zea mays* L.) in Suddan savannah of Nigeria. *ARPN J. Agric. Biol. Sci.* **3**(2): 1-5.

Prabhjyot-Kaur, Singh, H. and Hundal, S.S. 2006. Annual and seasonal climatic variabilities at Ludhiana, Punjab. *Jour. Agric. Physics.* **6**: 39-45.

Shinde, S.A., Patange, M.J. and Dhage, S.J. 2014. Influence of irrigation schedules and integrated nutrient management on growth, yield and quality of rabi maize (*Zea mays* L.). *Int. J. Curr. Microbiol. Appl. Sci.* **3**(12): 828-32.

Singh, S. and Singh, T.N. 2000. Response of maize crop to early and late summer sowing conditions. *Ind. J. Plant. Physiol.* **5**: 307-13.

Song, L. and Jin, J. 2020. Effects of sunshine hours and daily maximum temperature declines and cultivar replacements on maize growth and yields. *Journal of Agronomy* **10**: 1-21.

Tariq, J.A., Khan, M.J. and Usman, K. 2003. Irrigation scheduling of maize crop by pan evaporation method. *Pak. J. of Water Resources* **7**: 29-35.

Wheeler, T.R., Craufurd, P.Q., Ellis, R.H., Porter, J.R. and Prasad, P.V. 2000. Temperature variability and the yield of annual crops. *Agric. Ecosyst. Environ*. **82**: 159-167.

Zampieri, M., Russo, S., di., Sabatino S., Michetti, M., Scoccimarro, E. and Gualdi, S. 2016. Global assessment of heat wave magnitudes from 1901 to 2010 and implications for the river discharge of the Alps. *Science of the Total Environment* **571**: 1330–1339.

Received: 27 July 2022; Accepted: 1 October 2022