Journal of Agrometeorology 23 (2) : 176-182 (June 2021)

Formulation of weekly and monthly thumb rule models for prediction of potential productivity of sunflower in Punjab

JASPAL SINGH and PRABHJYOT-KAUR*

Department of Climate Change and Agricultural Meteorology
Punjab Agricultural University, Ludhiana - 141 004, India
*Corresponding author : prabhsidhu@gmail.com

ABSTRACT

A study was conducted to evaluate the effect of meteorological parameters on Sunflower crop by analyzing meteorological and crop data (2003-2017) for three locations (Ludhiana, Ballowal Saunkhari and Amritsar) and to develop weather based "Weekly and Monthly Thumb Rule Models" for predicting the potential yield of sunflower crop in Punjab. These climatic normals were used for comparing the actual data to evaluate the effect of meteorological parameters on the yield of sunflower. In Punjab, ideally humid (maximum relative humidity between 77% - 94%) weather from mid-February to mid-March is favourable for optimum growth and development of vegetative stage in crop. The warm temperature (>35˚C) during the seed development period after the flowering stage of sunflower is favourable for seed yield. However, heavy rainfall in the months of April and May with cloudy weather (sunshine hour < 9.2 hour) are not favourable for its productivity. The actual meteorological data of high yield crop years over the past 15 years were analyzed for different growth stages of sunflower to work out the critical ranges of meteorological parameters. Weather based "Thumb Rule Models" using the weekly and monthly meteorological data for different growth stages were formulated for use in developing the crop weather insurance term sheets and also predicting the potential yield of sunflower crop.

Key words: Climatic normal, meteorological parameters, Punjab, thumb rule model, sunflower

The sunflower (*Helianthus annuus* L.*,* Asteraceae) is an important *rabi* season oilseed crop which is also grown as forage crop due to its high protein content and other nutritional factors (Fozia *et al*, 2008). In Punjab it is grown on an area of around 8.5 thousand hectares with production of 15 thousand tonnes and productivity of 1762 kg ha^{-1} (Anonymous, 2018). In sunflower, optimum threshold temperature is 26–29˚C, and higher temperatures to optimum may cause heat stress (Rondanini *et al*, 2006). The plant is susceptible to heat stress particularly during flowering stage (Moriondo *et al*, 2011).Warm temperature is favourable for seed yield and yield contributing traits during grain filling stage in spring sown crop (Kaleem *et al*, 2009).

Sunflower matures in about 90-120 days after sowing with four critical growth stages , i.e., seedling, bud initiation/ knee high, flowering and seed development (Sharma 2012) and the information on critical limits of weather parameters for important crop stages is the basis for the formulation of term sheets for crop-weather insurances (Vishnoi *et al,* 2020). The crop is gradually gaining importance due to its wide adaptability to different crop seasons, soil types, drought tolerance traits and high economic returns per unit area and so its weather insurance is becoming vital. Hence a study was conducted to develop weather based "Weekly and Monthly Thumb Rule Models" for use in crop weather insurance as well as predicting the potential yield of sunflower crop in Punjab.

MATERIALS AND METHODS

Data collection

The crop data were obtained from Statistical Abstracts, Punjab covering a period of 15 years (2003 to 2017) for major sunflower growing locations, i.e. Ludhiana (30.90° N, 75.85° E), Ballowal Saunkhari (31.09° N, 76.38° E) and Amritsar (31.63° N, 74.87° E) which were then categorized as low, medium and high yield crop years.

The daily weather data (maximum and minimum temperature, maximum and minimum relative humidity, rainfall, rainy days, evaporation, sunshine hours and wind speed as per availability) for these locations were collected to work out the weekly and monthly climatic normal. These climatic normal were used for comparing the actual data to study the effect of meteorological parameters on yield of sunflower crop.

Table 1: Average monthly meteorological parameters during sunflower crop season (2003-2017)

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Number of Rainy Days (#)	Sunshine Hours (hours)	Evaporation (mm)	Wind Speed (km/hr)
	Max	Min	Max	Min					
					Ludhiana				
January	17.2	6.2	96	63	29.7	4	3.7	39.9	3.6
February	21.6	9.0	94	56	37.2	4	6.8	61.4	4.1
March	27.7	13.3	90	45	26.5	3	8.7	116.8	4.1
April	35.3	18.5	66	27	19.4	5	9.5	219.7	5.1
May	38.9	23.7	54	29	20.9	3	9.3	296.1	6.2
					Ballowal Saunkhri				
January	18.8	5.4	94	61	40.4	2	5.3	38.9	2.4
February	23.2	8.8	88	51	39.4	3	6.8	63.9	3.3
March	28.7	13.0	77	44	39.4	3	8.3	118.8	3.7
April	35.4	18.0	58	31	20.7	2	9.2	198.1	4.3
May	38.8	22.3	52	31	24.7	3	9.8	255.0	4.6
					Amritsar				
January	17.0	3.6	94	73	28.6	2	-	-	-
February	21.6	7.0	90	62	44.9	3	-	-	-
March	27.2	11.6	83	53	33.9	3	-	-	-
April	34.8	17.1	61	32	22.8	2	-	-	-
May	39.7	22.0	46	26	15.4	2	-	-	-

Table 2: Stage wise range of average meteorological parameters for sunflower crop at (2003-2017)

Crop growth stage	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	No. of rainy days (#)	Sunshine hours (hours)	Evaporation (mm)	Wind speed (km/hr)
	Max	Min	Max	Min					
					Ludhiana				
Sowing and emergence	16.1-20.0	5.4-7.4	96	58-66	2.3-10.7	0-2	3.5-6.2	7.4-11.7	3.3-4.2
Vegetative	20.3-29.6	8.3-14.2	89-95	42-58	5.9-16.2	0-2	6.1-8.8	13.7-29.2	3.7-4.5
Flowering	31.1-35.3	15.0-16.9	69-86	25-37	2.6-6.0	0-1	9.2-9.8	33.7-49.1	4.1-5.8
Grain filling	36.1-38.6	19.1-22.8	52-62	25-28	2.4-6.7	0-1	8.6-9.9	57.3-64.1	5.0-6.2
Physiological maturity	39.4-39.9	23.8-24.0	54-55	28-31	3.1-9.6	0-1	9.1-9.5	69.2-69.8	5.8-6.8
					Ballowal Saunkhri				
Sowing and emergence	17.6-21.3	4.5-7.0	91-94	55-65	4.7-15.2	0-1	4.1-6.5	7.0-12.5	2.2-2.6
Vegetative	21.8-30.4	8.1-14.6	74-91	40-54	6.6-14.3	0-1	6.3-8.5	13.9-30.7	3.3-3.9
Flowering	31.5-35.1	15.3-17.1	58-70	30-38	2.8-4.5	0-1	8.6-8.8	32.3-43.5	3.5-4.5
Grain filling	36.1-38.2	19.2-22.0	50-58	28-32	2.9-8.1	0-1	9.4-9.8	48.8-55.1	4.3-4.6
Physiological maturity	39.4-39.7	23.2-23.3	50-54	31-33	3.0-5.9	0-1	9.8-9.9	59.6-60.5	4.4-4.9
					Amritsar				
Sowing and emergence	15.9-19.9	2.9-5.0	92-95	70-78	2.3-12.2	0-1	-	-	-
Vegetative	20.4-28.9	6.2-13.1	81-92	49-63	5.2-13.7	0-1	-	-	-
Flowering	30.4-34.1	14.4-16.5	62-78	32-47	2.5-5.2	0-1	-	-	-
Grain filling	36.0-39.4	17.9-21.3	47-57	24-29	1.6-10.2	0-1	-	-	-
Physiological maturity	40.1-40.2	22.6-23.2	44-66	24-28	2.1-5.7	0-1	-	-	-

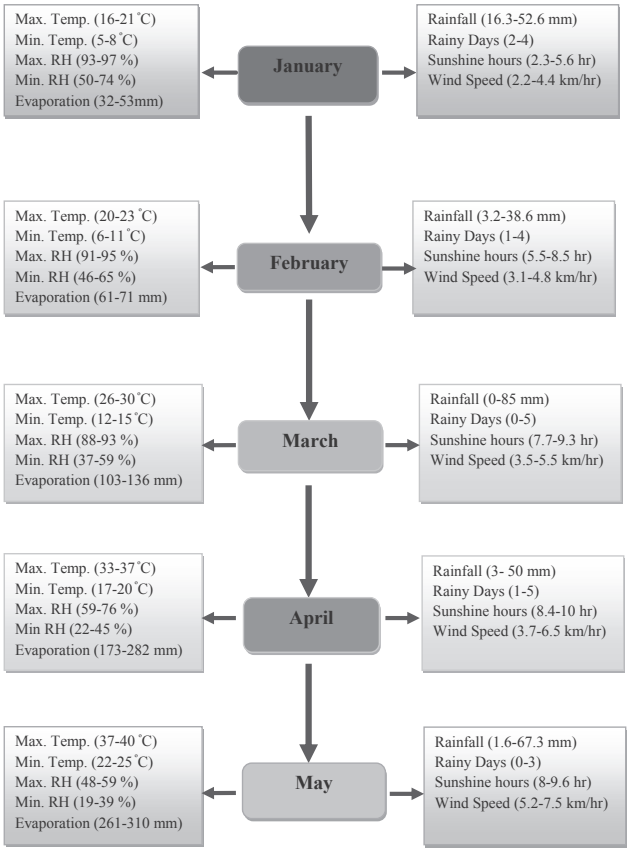

Fig. 1: Monthly thumb rule model for Ludhiana

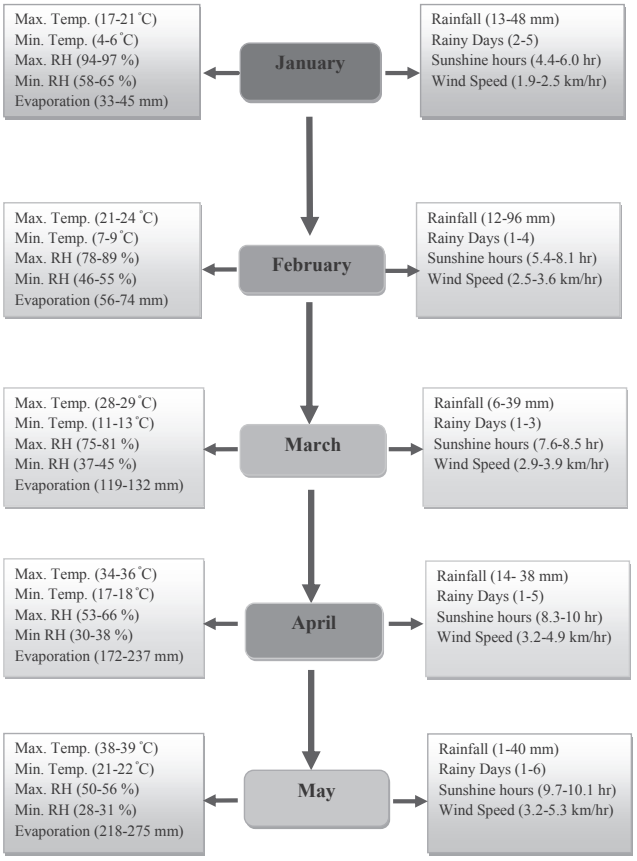

Fig. 2: Monthly thumb rule model for Ballowal Saunkhri

The data of different crop phenological stages (sowing and emergence, vegetative, flowering, grain filling and physiological maturity stages) were collected from the field experiments conducted under the DST (Department of Science & Technology) sponsored research project under the Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana.

Crop growth stage wise "critical limits" of the meteorological parameters

The stage wise actual ranges of different meteorological parameters for the potential productivity of sunflower crop at three different locations were worked out from the actual meteorological data of high yield crop year for calculation of "critical Limits" of the different meteorological parameters for sunflower crop. On the basis of the "Critical limits" of various meteorological parameters, weather based "Weekly and Monthly Thumb Rule Models" for predicting the potential yield were developed.

Thumb rule models for predicting the potential yield of sunflower crop in Punjab

On the basis of "Critical Limit" of various meteorological parameters, i.e., temperature (maximum and minimum), rainfall, sunshine hours, relative humidity (maximum and minimum) etc. of the crop and meteorological data, the weekly and monthly thumb rule models for predicting potential yield of sunflower under Punjab conditions were worked out.

RESULTS AND DISCUSSION

Average of monthly meteorological parameters

The actual daily meteorological data (2003-2017) collected for three locations in the state were analysed and their respective monthly average were worked out. Further, monthly average data were cloned from January to May. For sunflower, a month wise actual range of normal monthly meteorological parameters in Punjab state were also worked out (Tables 1).

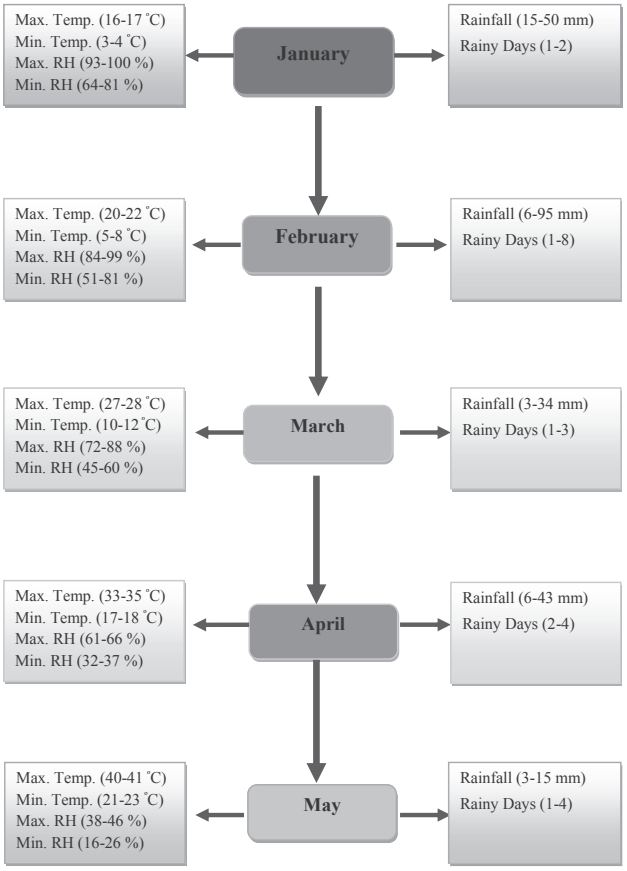

Fig. 3: Monthly thumb rule model for Amritsar

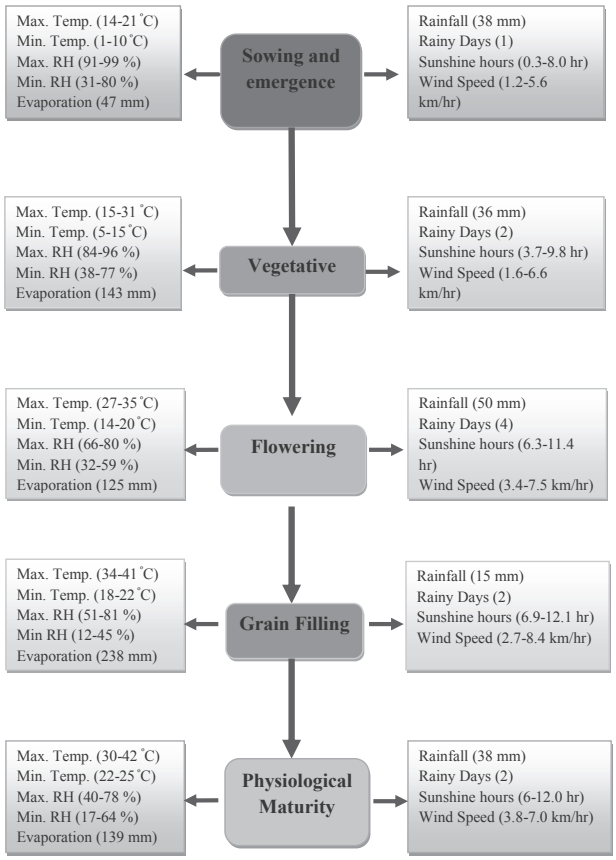

Fig. 4: Weekly thumb rule model for Ludhiana

In Punjab during January month, the range of actual normal of monthly maximum/minimum temperature are 17.0-18.8°C/3.6-6.2°C, maximum /minimum relative humidity are 94-96% / 60-73%, rainfall are 29.7-40.4 mm in rainy days of 2-4, sunshine hour are 3.7 – 5.3 hour and wind speed are 2.4-3.6 km/hr. While during the February month, the range of actual normal of monthly maximum/minimum temperature are 21.6-23.2°C/7.0-9.0 °C, maximum /minimum relative humidity are 88-94% / 51-62%, rainfall are 37.2-44.9 mm in rainy days of 3-4, sunshine hour are 6.0 – 7.0 hour and wind speed are 3.3-4.1 km/hr.

In the month of March the average range of actual monthly maximum/minimum temperature are 27.2-28.7 °C/11.6-13.3 °C, maximum /minimum relative humidity are 77-90% / 45-53%, rainfall are 26.5-39.4 mm in 1-3 rainy days, sunshine hour are 8.3 – 8.7 hour and wind speed are 3.7-4.1 km/hr, respectively. While during April the range of actual normal of monthly maximum/minimum temperature are 34.8-35.3°C/17.1-18.5°C, maximum /minimum relative humidity are 58-66% / 27-32%, rainfall are 19.4-22.8 mm in 2-5 rainy days, sunshine hour are 9.2 – 9.5 hour and wind speed are 4.3-5.1 km/hr.

At maturity time during the May the range of actual monthly maximum/minimum temperature are 38.8-39.7°C/22.0-23.7°C, maximum /minimum relative humidity are 46-54% / 26-31%, rainfall are 15.4-24.7 mm in 2-3 rainy days, sunshine hour are 9.3 – 9.8 hour and wind speed are 4.6-6.2 km/hr, respectively.

Monthly thumb rule models for predicting the potential yield of sunflower

On the basis of normal of meteorological parameters during the high yield crop years of sunflower crop the "Monthly Thumb Rules Models" were developed (fig 1-3) for predicting the yield of sunflower crop for three different locations of Punjab. The favourable range of meteorological parameters for sunflower crop are :

During January month the optimum range of meteorological parameters are : maximum / minimum temperature 16-21°C/3-8°C, maximum / minimum relative

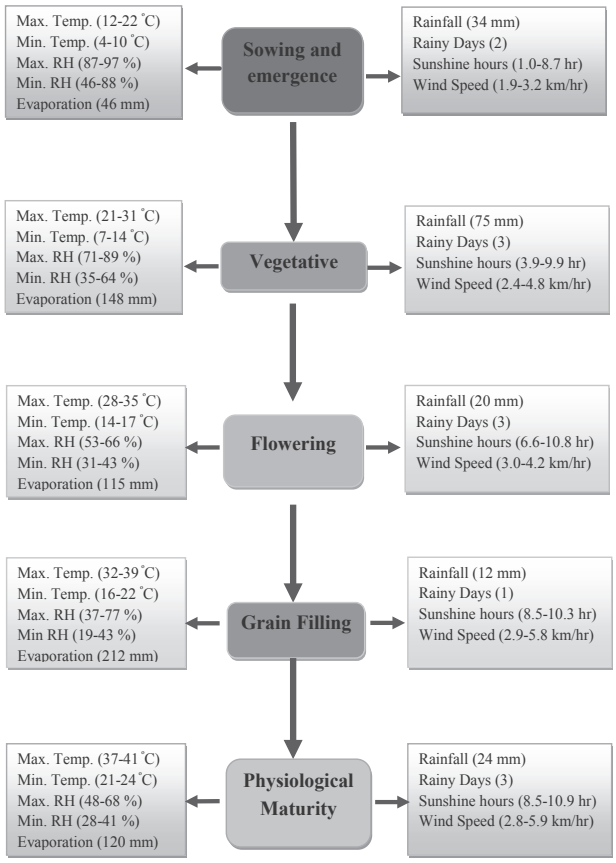

Fig. 5: Weekly thumb rule model for Ballowal Saunkhri

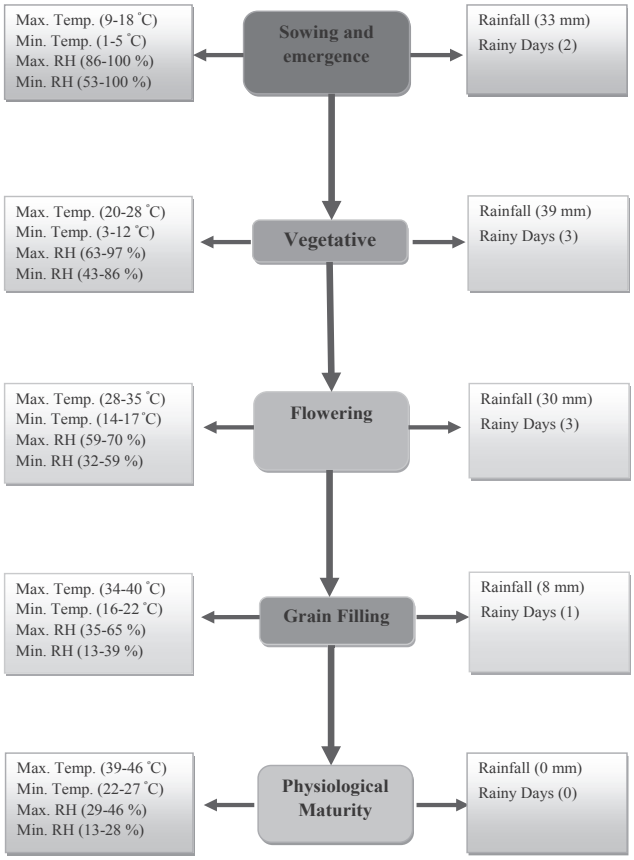

Fig. 6: Weekly thumb rule model for Amritsar

humidity 93-100% / 50-81%, rainfall of 13-52.6 mm in 1-5 rainy days, sunshine hour 2.3-6.0 hours and wind speed 1.9-4.4 km/hr for potential productivity of Sunflower. While during the February, the optimum range of meteorological parameters are : maximum / minimum temperature 20-24°C/5-11°C, maximum / minimum relative humidity 78-95% / 46-99%, rainfall of 3.2-95 mm in 2-3 rainy days, sunshine hour 4.0-10.0 hours and wind speed 2.0-5.5 km/hr for potential productivity of Sunflower.

In the month of March, the optimum range of meteorological parameters are : maximum / minimum temperature 28-35°C/14-17°C, maximum / minimum relative humidity 60-70% / 32-50%, rainfall of 20-50 mm in 3-4 rainy days, sunshine hour 6.5-11.0 hours and wind speed 2.0-4.0 km/hr for potential productivity of Sunflower. While during April, the optimum range of meteorological parameters during April month are : maximum / minimum temperature 34-40°C/16-22°C, maximum / minimum relative humidity 40-70% / 15-43%, rainfall of 8-15 mm in 1-2 rainy days, sunshine hour 7.0-12.0 hours and wind speed 3.0-7.0 km/hr for potential productivity of Sunflower.

At maturity time during May, the optimum range of meteorological parameters during May are : maximum / minimum temperature 35-42°C/ 22-25°C, maximum / minimum relative humidity 40-68% / 20-40%, rainfall of 24-38 mm in 2-3 rainy days, sunshine hour 7.0-11.5 hours and wind speed 3.0-6.5 km/hr for potential productivity of Sunflower in Punjab.

Crop stage wise average range of meteorological parameters for sunflower crop

The sunflower crop data were categorized into various crop growth stages, i.e, sowing and emergence, vegetative stage, flowering stage, grain filling stage and physiological maturity stage. The actual daily meteorological data were analysed as per the various crop stages to work out their actual ranges (Table 2).

In Punjab, during sowing and emergence the range of normal weekly maximum/minimum temperature are 15.9-21.3°C/2.9-7.4°C, maximum /minimum relative

humidity are 91-97% / 55-78%, rainfall are 32.7-43.2 mm in rainy days of 1-2, sunshine hour of 3.5 – 6.5 hour and wind speed 2.2-3.7 km/hr. The vegetative period extends from 06 to 12 SMW and the range of normal weekly maximum/ minimum temperature are 20.3-30.4°C/7.1-14.6°C, maximum /minimum relative humidity are 74-95% / 40-63%, rainfall are 57.9-73.2 mm in rainy days of 1-2, sunshine hour of 6.1 – 8.8 hour and wind speed 3.3-4.3 km/hr.

The flowering period extends from 13 to 15 SMW and the range of normal weekly maximum/minimum temperature are 30.4-35.3°C/14.4-17.1°C, maximum / minimum relative humidity are 58-86% / 25-47%, rainfall are 10.2-11.6 mm in 1 rainy day, sunshine hour of 8.6 – 9.8 hour and wind speed 3.5-5.2 km/hr. The grain filling period of sunflower crop in Punjab extends from 16 to 19 SMW and the range of normal weekly maximum/minimum temperature are 36.0-39.4°C/17.9-22.8°C, maximum /minimum relative humidity are 47-62% / 24-32%, rainfall are 15.3-22.2 mm in 1 rainy day, sunshine hour of 9.4 – 9.9 hour and wind speed 4.3-6.2 km/hr.

The physiological maturity period extends from 20 to 21 SMW and the range of normal of weekly maximum/ minimum temperature are 39.4-40.1°C/22.6-24.0°C, maximum /minimum relative humidity are 44-55% / 24-33%, rainfall are 7.8-12.7 mm in 1 rainy day, sunshine hour of 9.1 – 9.9 hour and wind speed 4.4-6.8 km/hr.

Weekly thumb rule models for predicting the potential yield of sunflower crop

On the basis of critical limits of meteorological parameters for different growth stages during high yield crop years of sunflower crop the weather based "Weekly Thumb Rules Models" were developed (fig 4-6) for predicting the yield of sunflower crop for three different locations (Ludhiana, Ballowal Saunkhri and Amritsar) of Punjab.

In Punjab, the critical limits of meteorological parameters during sowing and emergence period are : maximum / minimum temperature 12-21°C/2-8°C, maximum / minimum relative humidity 88-99% / 43-89%, rainfall of 33-38 mm in 1-2 rainy days, sunshine hour 0.6-8.3 hours and wind speed 1.5-4.5 km/hr for potential productivity of Sunflower. The vegetative period extends from 06 to 12 SMW and the range of "Critical Limit" of meteorological parameters are : maximum / minimum temperature 19-31°C/5-13°C, maximum / minimum relative humidity 72-94% / 39-75%, rainfall of 36-75 mm in 2-3 rainy days, sunshine hour 4.0-10.0 hours and wind speed 2.0-5.5 km/hr.

The flowering period extends from 13 to 15 SMW and the range of "Critical Limit" of meteorological parameters period are : maximum / minimum temperature 28-35°C/14-17°C, maximum / minimum relative humidity 60-70% / 32-50%, rainfall of 20-50 mm in 3-4 rainy days, sunshine hour 6.5-11.0 hours and wind speed 2.0-4.0 km/hr for potential productivity of Sunflower. The grain filling period of sunflower crop in Punjab extends from 16 to 19 SMW and the range of "Critical Limit" of meteorological parameters are : maximum / minimum temperature 34-40°C/16-22°C, maximum / minimum relative humidity 40-70% / 15-43%, rainfall of 8-15 mm in 1-2 rainy days, sunshine hour 7.0-12.0 hours and wind speed 3.0-7.0 km/hr for potential productivity of Sunflower.

The physiological maturity period extends from 20 to 21 SMW and the range of "Critical Limit" of meteorological parameters during the physiological maturity period are : maximum / minimum temperature 35-42°C/ 22-25°C, maximum / minimum relative humidity 40-68% / 20-40%, rainfall of 24-38 mm in 2-3 rainy days, sunshine hour 7.0-11.5 hours and wind speed 3.0-6.5 km/hr for potential productivity of Sunflower in Punjab.

CONCLUSION

Weather is one of the most important input variable which influences the growth of crop starting from sowing to harvesting. The information on effect of these weather variable on crop growth stages is vital while formulating the agro advisory for the farmers (Chattopadhyay 2021). The crop yield predicted by these thumb rule models can be helpful for extension workers as well as policy planners.

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Received : September 2019 : Accepted : May 2021