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Studies on Crop Weather Calendar of Brinjal Crop in Eastern Uttar Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An investigation was carried out on studies of crop weather calendar on brinjal crop in Eastern Uttar Pradesh has been prepared with objectives to study climatic normal of past 21 years from 2000-21 at Department of Agricultural Meteorology, College of Agriculture, Acharya Narendra Dev University of Agriculture and Technology, Ayodhya, Uttar Pradesh. Climatic data for brinjal crop in *Kharif* season has been taken from 27th to 48th Standard Meteorological Week (SMW). From the crop weather calendar of brinjal, it was revealed that low temperatures are lethal for brinjal seedlings, so temperature should not be less than 18 °C before the transplanting of the brinjal seedlings into the field. Rainfall during vegetative stage was 140-150 mm found congenial for the better yield of the plant. The growth of the crops is severely affected when temperature falls below 17 °C. It can be successfully grown as a rainy season and summer season crop. It was revealed that, Tmax 23.3-

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31.8 °C, Tmin 8.4-25.1 °C, rainfall of 0.5-10 mm during 31st to 45th SMW with RHm 90.9-95.6% and RHe 52.1-79.6 were found conducive conditions for the infestation of shoot/fruit borer. It was observed that Fusarium wilt of brinjal was significant during October (41st week) to December (52nd week), when Tmax 23.5- 33.0 °C, Tmin 12.1-26.7 °C, RHm 83.9-87.8%, RHe 48.1-71.5% and rainfall of 0-0.75 mm. It has been found that the severity of fusarium wilt increases with decrease in temperature and high relative humidity and very low rainfall.

Keywords: Crop weather calendar; brinjal crop; crops grown; production.

1. INTRODUCTION

Brinjal (*Solanum melongena* L.) belongs to the family Solanaceae and it is one of the popular vegetable crops grown in India, as well as, other parts of the world. Brinjal is a warm season crop that requires a long period of warm weather to grow. It is widely grown in the hemispheres with warmer climates, although it is most commonly used as a Mediterranean or Middle Eastern vegetable. It is quite vulnerable to frost. It thrives best in temperatures ranging from 13 to 21 °C on a regular basis. It can be cultivated effectively in both the rainy and summer seasons, and at an elevation of 1200 meters above mean sea level. Low temperatures, especially below 15 °C, have an impact on plant development and fruit quality. High temperatures and low humidity might result in excessive flower drop and poor fruit settings. It thrives in places with moderate rainfall, ranging from 600 to 1000 mm. It can't tolerate a wide range of rain, especially during flowering and fruiting. This crop is subjected to attack by many insect pests throughout its growth period which act as limiting factor in its profitable cultivation. Uttar Pradesh ranked 11th in terms of Brinjal production that was 312.98 tonnes in 2021-22 that is Uttar Pradesh shared 2.45% in brinjal production of India. Among different districts of Eastern Uttar Pradesh, Ayodhya had the highest production of Brinjal in 2020-21 and that was 7.965 MT.

Weather related factors are significant in agricultural production. Climate and soil are two crucial resources that assist with crop planning Studying the effects of temperature, rainfall, relative humidity, brilliant sunlight hours, wind speed, and evaporation on crop phenology and insect incidence is crucial for this aim. So, it is highly possible that farm operations planned in conjunction with meteorological information will reduce the costs of inputs and different field operations. The "Crop Weather Calendar" is a pictorial representation of detailed information for a crop in terms of sowing period and duration of important phenological stages in its life cycle, as well as the optimal climatic requirements during various stages of the crop and the actual and normal weather for that station/location [1].

Crop weather calendars could be a useful tool for researchers and farmers. It's a tool that shows the average weather for each week, as well as the planting, sowing, and harvesting seasons of regionally adapted crops in a very specific agro-ecological zone. It's possible to include information on pest disease infestations by stage. This calendar depicts the weather and operations to be focused on month by month throughout the phase.

The current study, titled "Studies on crop-weather calendar of Brinjal crop for the Eastern Uttar Pradesh," was carried out with the objectives to find out the optimum climatic conditions and to observe the weather parameters according to the phenological stages for higher yield and to evaluate the congenial weather for pests and diseases incidence. So that this tool supports farmers and agricultural extensionists in taking appropriate decisions on a particular crop and their sowing period respecting the agroecological dimension.

2. MATERIALS AND METHODS

Eastern Uttar Pradesh covers the 28 districts namely Allahabad, Ambedkar Nagar, Amethi, Azamgarh, Bahraich, Ballia, Balrampur, Basti, Chandauli, Deoria, Faizabad, Ghazipur, Gonda, Gorakhpur, Jaunpur, Kaushambi, Kushinagar, Maharajganj, Mau, Mirzapur, Pratapgarh, Sant Kabir Nagar, Sant Ravi Das Nagar, Shravasti, Siddharth Nagar, Sonbhadra, Sultanpur, and Varanasi. Rainfall is adequate with a normal of 839 mm. The climate is dry sub-humid to moist sub-humid.

Weather data for the last twenty years (2000-21) were collected from department of Agricultural meteorology, ANDUAT, Kumarganj, Ayodhya and Indian Meteorological Department (IMD). Weekly climatic normal for standard

meteorological weeks (1st-52nd) for this location were computed. Weekly average of weather parameters was computed for the SMW (1st-52nd). These normal meteorological data sets were arranged in weekly format for cropping season from the month of sowing to the harvest of the brinjal crop for Ayodhya district as cited in Table 1.

Crop weather calendar for brinjal was formulated by combining the weekly climatic averages and phenological calendar for the crop along with optimum weather criteria needed at different phenological stages of the crop. For knowing the high yielding values for optimum climatic normal data from last ten years (2011-21) was used to find out the stage wise phenophases normal for better yield of the crop. The data for high productivity year of the crop, collected from the National Horticultural Board (www.nhb.gov.in) cited in Table 2. The range of different meteorological parameters for the high productivity of brinjal was worked out from the actual meteorological data of high productivity crop year.

Weather conditions that favour pest incidence and the nature of weather alerts were gathered. The goal of this study was to look for crop weather pest interactions in brinjal crop for *Kharif* season. The research is based on pest investigation data of brinjal crop that is collected from the Department of Entomology, ANDUAT Kumarganj, Ayodhya and weather data averaged over the last five years.

2.1 Structure of Crop Weather Calendar

The crop weather calendar is divided into three parts: the upper part, which contains location-specific weather data for the crop growing season, the middle part, which depicts the crop's typical life history in the form of a diagram, and the lower part, which contains the crop's typical life history in the form of a Table. Sowing, germination/emergence, transplanting, vegetative growth, flowering, grain formation, and maturity period are all examples of important "growth phases" associated to the crop. In addition, the middle part of the calendars revealed the appropriate weather conditions for the crop (stage wise or for the entire crop growth time), which will result in a high crop yield. In the bottom section, favorable weather conditions for pest and disease incidence are reported.

Table 1. Climatic normal for weather parameters (2000-21)

Week/ weather Parameter	T min(°C)	T max(°C)	RHm (%)	RHe(%)	Rainfall (mm)	Evp (mm/day)	Bss (hrs.)
1	6.84	19.3	89.7	63.0	4.5	11.6	4.5
2	6.22	19.4	86.0	61.0	1.1	13.0	4.7
3	7.20	20.7	87.1	57.6	5.0	13.6	5.7
4	7.00	21.1	88.6	57.0	5.0	14.8	7.2
5	7.58	22.8	87.9	53.0	1.2	17.4	6.7
6	8.61	24.5	89.9	52.6	5.4	19.8	7.1
7	9.61	23.6	86.5	50.8	3.3	20.6	8.7
8	10.81	27.1	86.4	46.2	5.3	24.2	8.5
9	12.00	27.9	83.2	43.7	3.4	25.5	8.3
10	12.28	29.6	79.7	42.6	4.0	26.2	8.5
11	13.62	30.7	78.9	40.7	2.4	29.1	8.4
12	15.07	33.2	74.2	35.0	0.4	33.2	8.4
13	16.10	34.1	72.0	30.9	0.4	35.2	8.7
14	16.99	36.3	68.6	30.8	0.7	39.2	8.8
15	19.15	38.0	61.8	28.5	0.7	46.4	8.8
16	21.08	38.3	66.2	32.3	1.3	45.1	9
17	21.56	40.0	63.7	31.8	3.4	48.4	9.1
18	23.05	37.4	69.0	33.0	4.9	46.8	9.3
19	23.86	38.8	67.3	34.0	6.2	50.4	9.3
20	23.97	38.9	70.0	35.9	5.1	51.8	9.2
21	25.52	38.4	71.0	37.3	6.0	50.3	8.4
22	25.39	38.4	70.0	41.6	14.6	49.6	8.6
23	25.95	38.3	73.4	44.3	24.1	49.4	8.1
24	26.43	37.4	73.7	49.5	26.3	45.6	7.2

Week/ weather Parameter	T min(°C)	T max(°C)	RHm (%)	RHe(%)	Rainfall (mm)	Evp (mm/day)	Bss (hrs.)
25	26.67	35.5	80.8	58.4	39.4	40.2	5.6
26	26.75	35.4	82.5	59.6	63.8	35.6	4.6
27	26.55	33.6	85.5	70.2	67.0	31.2	4.9
28	25.86	33.2	87.8	70.9	55.0	34.6	4.2
29	26.03	33.0	88.1	72.3	70.0	30.0	4.8
30	26.30	32.8	88.7	72.3	44.3	28.2	5.7
31	26.22	32.0	87.9	71.4	42.5	28.2	4.9
32	26.40	33.2	86.0	71.0	39.1	31.4	4.9
33	26.14	33.2	90.4	74.6	69.6	26.4	4.4
34	26.16	32.4	89.8	73.7	50.2	29.9	4.4
35	26.04	33.2	89.3	70.2	30.5	32.3	5.4
36	25.80	32.9	87.2	70.0	35.7	30.4	4.6
37	25.64	32.8	89.4	70.0	36.8	31.3	5.0
38	24.96	32.6	89.3	70.1	35.2	30.6	6.0
39	23.77	32.6	88.6	69.2	39.8	29.3	6.5
40	22.92	32.6	86.5	65.2	13.6	31.6	7.1
41	20.91	32.9	85.5	60.2	7.2	31.0	7.5
42	19.03	32.0	87.1	53.3	4.9	29.9	8.2
43	16.97	31.3	87.2	50.7	1.5	26.2	7.6
44	15.38	30.4	87.5	48.3	0.0	25.0	8.3
45	13.90	29.9	88.7	49.9	0.2	23.7	7.9
46	13.12	28.8	88.7	50.1	0.6	23.2	7.4
47	11.64	27.6	85.2	47.5	0.0	21.4	7.1
48	10.50	27.2	87.4	47.7	0.0	19.4	6.8
49	9.10	25.5	88.1	48.4	0.0	28.1	6.8
50	8.64	24.0	88.6	54.0	1.9	18.4	6.6
51	7.24	22.2	90.0	56.9	0.0	20.4	5.9
52	6.72	22.1	91.3	58.7	2.0	28.2	5.8

Table 2. Highest productivity year for brinjal at Ayodhya

Year	2017	2018	2019	2020	2021
Productivity of Brinjal qha^{-1}	73.41	73.51	75.95	78.53	79.65

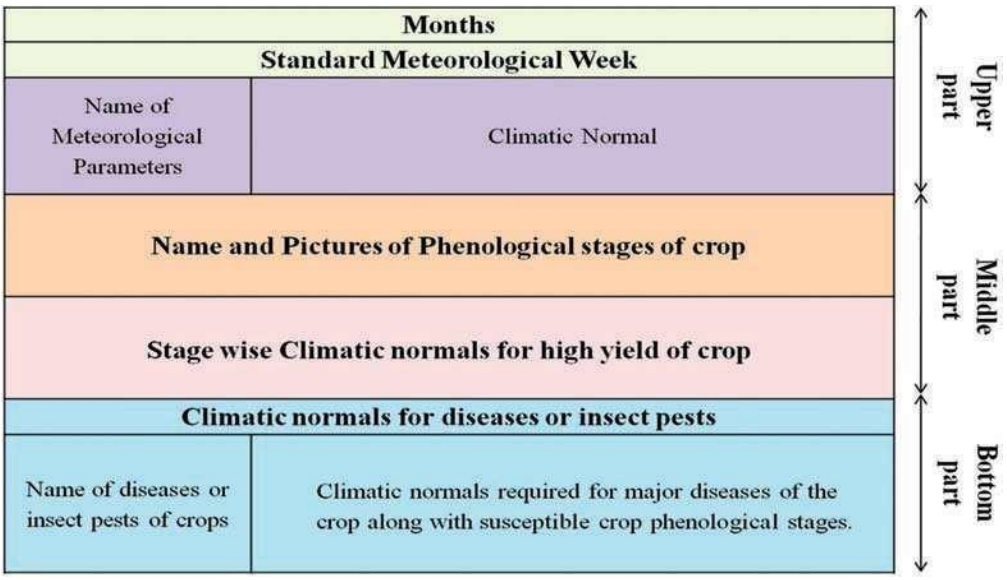

Fig. 1. Structure of crop weather calendar

3. RESULTS AND DISCUSSION

3.1 Crop Weather Calendar of Brinjal for Ayodhya District

3.1.1 Climatic normal for brinjal

Data pertaining to climatic normal for different weather parameters (averaged over 21 years) have been presented in Table 1 and depicted in Fig. 2. The climatic normal for Brinjal has been taken from SMW 27th to 48th met. Week (from sowing to harvesting). The highest normal rainfall 70.0 mm) was found during 29th SMW followed by 69.6 mm during 33rd SMW and 67.0 mm in 27th SMW. The highest normal Tmax (33.2 °C) found during 27th SMW and Tmin (26.6 °C) was found during 48th SMW. Highest RHm was during 33rd SMW (90.4%) and minimum RHe found during 47th SMW (47.5%). Crop sown during 27th SMW, as the Brinjal is a long and warm season crop so it can be successfully grown as a rainy season and summer season crop.

3.1.2 Phenophases wise weather for better yield of brinjal

Brinjal took crop duration of 140-150 days to complete its life cycle in Ayodhya district. Data presented in Fig. 2 reveals that Brinjal seed had taken 7-14 days to emerge. During seed germination, Tmax and Tmin were found 34-36 °C and 25.5-27.5 °C respectively, RHm 91-95% and RHe 64-70% were found conducive for better yield. Optimum temperature required is between 28 °C for day and 20 °C for night for the seed germination in Brinjal, as reported by Chen et al. [2,3].

At transplanting and plant establishment of the crop, Tmax and Tmin were observed 33-34 °C and 25-28 °C, respectively, were found favorable for better yield because low temperatures are lethal for seedlings, so temperature should not be less than 18 °C before the transplanting of the brinjal seedlings into the field. At vegetative stage Tmax 32-35 °C, T min 26-29 °C, RHm 89-95%, RHe 67-74% and BSS 4-6 hrs/day were found conducive for Ayodhya district [4,5].

During the vegetative stage Tmax and Tmin were found 32-35 °C and 26-29 °C, respectively while RHm and RHe were found 89-95% and 67-74%, respectively and BSS was found 4.0-6.0 hr/day. Rainfall during vegetative stage was found 140-150 mm was found congenial for the expansion of the leaves and chlorophyll content and hence for the better yield of the plant [6].

CROP WEATHER CALENDAR

CROP NAME : BRINJAL | DURATION 140-150 DAYS | STATE: UTTAR PRADESH | DISTRICT: FAIZABAD

CLIMATIC NORMALS

MONTHS	JULY				AUGUST					SEPTEMBER				OCTOBER					NOVEMBER			
Std WEEKS	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
T Max. (°C)	33.6	33.2	32.9	32.8	32	33.2	33.1	32.3	33.1	32.3	33.1	32.8	32.9	32.6	32.5	32.6	32.9	32.0	31.3	30.3	29.9	27.5
T Min. (°C)	26.6	25.9	26	26.3	26.2	26.4	26.1	26.2	26	25.8	25.6	25	23.8	22.9	20.9	19	17	15.4	13.9	13.1	11.6	10.5
RHe(%)	70.2	70.9	72.3	72.3	71.4	71	74.6	73.7	70.2	70	70.0	70.1	69.2	65.2	60.2	53.3	50.7	48.3	49.9	50.1	47.5	47.7
RHm(%)	85.5	87.8	88.1	88.7	87.9	86.0	90.4	89.8	89.3	87.2	89.4	89.3	88.6	86.5	85.5	87.1	87.2	87.5	88.7	88.7	85.2	87.4
Rain(mm)	67.0	55.0	70.0	44.3	42.5	39.1	69.6	50.2	30.5	35.7	36.8	43.7	39.8	13.6	7.2	4.9	1.5	0.0	0.2	0.6	0.0	0.0
evp(mm)	32.8	34.6	30.0	28.2	28.2	31.4	26.4	29.9	32.3	30.4	31.3	30.6	29.3	31.6	31.0	29.9	26.2	25.0	23.7	23.2	21.4	19.4
BSS(hr/day)	4.6	4.0	3.9	3.7	4.4	5.1	4.2	4.5	5.5	5.2	5.1	5.4	6.1	6.8	7.2	7.0	7.2	6.5	6.2	6.2	6.2	5.9

Phenophase wise weather for better yield

Phenophase	seed germination	Transplanting to plant establishment	Vegetative stage	Flower initiation to first picking	Harvesting
Duration (day)	7-14 days	10	30	30	60
T Max. (°C)	34-36	33 -34	32-35	33-34	27-31
T Min. (°C)	25.5-27.5	25-28	26-29	25-27	18-22
RHe(%)	64-70	65-69	67-74	65-71	57-61
RHm(%)	91-95	92-97	89-95	92-98	89-92
WS(kmph)	2.2-3.2	2.9-3	2.5-4.3	5.0-8	1.8-2.3
BSS(hr/day)	4.0-5.0	3.0- 4.0	4.0- 6.0	5.0-6.0	5.0-7.0
Rain(mm)	38-40	75-80	140-150	87-90	42-50
Eva(mm)	6.1-6.4	6.2-6.3	5.9-6.1	5.5-5.8	4.1-5.2

Congenial Weather for pest/disease incidence

Shoot / fruit borer	Tmax. 23.3-31.8°C, Tmin. 8.4-25.1°C, RHm 90.9-95.6% ,RHe 52.1-79.9% RF 0-78mm
Fusurium wilt of Brinjal	Tmax. 23.5-33.0°C, Tmin.12.1-26.7°C, RHm 83.9-87.8% ,RHe 48.1-71.5%

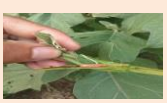

Fig. 2. Crop weather calendar of Brinjal crop

Table 3. Weather parameters for shoot/fruit borer of brinjal (Averaged over 5 years)

Std. MET Week No	T max (^{0}C)	T min (^{0}C)	RHm %	RHe %	RF (mm)	Mean % Shoot Infestation	Mean% Fruit Infestation
31	32.1	26.3	90.9	76.2	65	0.40	0
32	33.0	26.7	88.8	75.9	78	1.20	0
33	32.8	26.5	90.5	75.2	48	4.60	0
34	32.2	26.2	93.5	77.2	38	8.63	0
35	33.1	26.1	88.1	74.2	60	14.7	0
36	21.8	26.3	92.1	71.2	61	19.3	2.4
37	20.8	25.9	94.0	70.1	40	23.1	5.6
38	19.2	25.5	93.2	73.9	25	32.4	9.1
39	18.7	24.3	91.9	72.1	35	38.4	16.7
40	20.0	23.1	93.9	64.2	43	36.8	23.8
41	21.6	22.1	91.8	61.2	64	34.2	30.1
42	22.7	20.2	90.9	55.2	15	33.1	35.1
43	23.4	16.8	91.2	48.9	4	31.2	39.2
44	24.7	15.5	87.7	44.2	0	28.7	33.6
45	27.4	14.0	87.7	48.2	0	27.2	28.1
46	27.2	14.4	90.5	57.2	0	25.2	25.6
47	28.8	11.7	94.6	50.2	0	25.1	22.9
48	29.8	8.9	90.6	51.2	0	24.6	19.8

Table 4. Weather parameters for fusarium wilt of brinjal (Averaged over 5 years)

Std. MET. Week No.	T max (0C)	T min (0 C)	RHm %	RHe %	RF (mm)	% Disease severity of *Fusarium* wilt
31	32.1	26.3	90.9	76.2	65	0
32	33.0	26.7	88.8	75.9	78	7.8
33	32.8	26.5	90.5	75.2	48	17.8
34	32.2	26.2	93.5	77.2	38	20.1
35	33.1	26.1	88.1	74.2	60	23.5
36	21.8	26.3	92.1	71.2	61	27.9
37	20.8	25.9	94.0	70.1	40	30.7
38	19.2	25.5	93.2	73.9	25	31.1
39	18.7	24.3	91.9	72.1	35	32.5
40	20.0	23.1	93.9	64.2	43	32.8
41	21.6	22.1	91.8	61.2	64	34.5
42	22.7	20.2	90.9	55.2	15	35.8
43	23.4	16.8	91.2	48.9	4	36.7
44	24.7	15.5	87.7	44.2	0	38.5
45	27.4	14.0	87.7	48.2	0	39.6
46	27.2	14.4	90.5	57.2	0	40.2
47	28.8	11.7	94.6	50.2	0	42.6
48	29.8	8.9	90.6	51.2	0	45.8
49	25.2	10.2	97.7	47.9	0	47.7
50	23.9	9.5	85.9	51.3	4	48.9
51	21.2	6.5	92.9	63.2	0	50.6
52	19.6	6.4	93.2	64.9	3	51.4

Due to water stress, growth and leaf expansion are first affected, followed by a decrease in rates of transpiration due to partial stomatal closure potentially. So, it causes significant reduction in dry matter and chlorophyll content at high water stress as reported by [7,8,9,10]. While at flower initiation stage Tmin 25-27 °C, Tmax 33-34 °C, RHm 92-98% and BSS more than 5.5 hrs/day were found conducive for better yield. At harvesting stage T max and T min were found 27-31 °C and 18-22 °C respectively, RHm and RHe were found 89-92% and 57-61%, respectively and rainfall was found 0-24 mm. The growth of the crop is severely affected when

temperature falls below 17 ºC. It can be successfully grown as a rainy season and summer season crop [11,12,13].

3.2 Congenial Weather for Insect and Diseases of Brinjal

3.2.1 Shoot /fruit borer of brinjal, *Leucinodes orbonalis* Guenee

Data presented in Fig. 2 reveals that, Tmax 23.3-31.8 °C, Tmin 8.4-25.1 °C, rainfall of 0.5-10 mm during 31st to 45th SMW with RHm 90.9-95.6% and RHe 52.1-79.6 were found conducive conditions for the infestation of shoot/ fruit borer. The shoot infestation of the pest occurred first time during first week of August (32nd week), the infestation was found increasing 32nd SMW onwards with maximum temperature and then again, the infestation percentage was found fluctuating with temperature from 40th week (Table 3). While, the fruit damage was first time noticed during the first week of September (36th SMW) and maximum infestation was found during 43rd SMW and then again found decreasing from 48th SMW (Table 3). The infestation of shoot/ fruit borer was found increasing with the Tmax and RHe. Shoot/fruit borer infestation was positively correlated with maximum temperature and morning relative humidity and negatively correlated with minimum temperature and evening relative humidity and rainfall. Similar results were reported by [14,15,16].

3.2.2 Fusarium wilt of brinjal, *Fusarium oxysporum* f. sp. *melongenae*

Data presented in Fig. 2 reveals that, Tmax 23.5-33.0 °C, Tmin 12.1-26.7 °C, RHm 83.9-87.8%, RHe 48.1-71.5% and rainfall of 0-0.75 mm. These conditions were observed from August (31st SMW) to December (52nd week) and were significant during October (41st week) to December (52nd SMW) (Table 4) and were found conducive weather requirements for fusarium wilt. It has been found that the severity of fusarium wilt increases with decrease in temperature and high relative humidity and very low rainfall. [17] was also found the similar results.

4. CONCLUSIONS

Crop weather calendar of Brinjal crop contains a detailed information on Brinjal regarding its climatic requirements from sowing of crop to harvesting of crop with additional information about the favorable weather conditions for phenological stage of the crop *i.e.,* germination to harvesting stages as well as major attacking pest and disease of Brinjal *viz.,* shoot and fruit borer and *Fusarium* wilt of Brinjal. Crop contingency planning and Agromet advisory services are a couple of the ways to deal with this kind of crisis, which calls for knowledge of crop phenology and the impact of environmental factors on crop growth [12,13] In this situation, the crop weather calendar acquires a significant role. Crop insurance experts can use the crop weather calendars to determine crucial moments and the necessary weather indices. It will be extremely helpful in creating insurance products, agricultural contingency plans, and Agromet advisory bulletins [18,19,20].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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