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Preparation of crop weather calendar for pigeon pea (*Cajanus cajan* L. Millsp.)

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Abstract
During the academic year 2024-25, a study was conducted at the Department of Agricultural Meteorology, College of Agriculture Parbhani, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, titled *"*Preparation of a Crop Weather Calendar of Pigeon Pea (*Cajanus cajan* L. Millsp.)*"*. The key objectives of this investigation were to: To prepare crop weather calendar of Pigeonpea. A decadal climatic analysis for the Parbhani region revealed considerable variability in weather patterns. Fluctuating temperature trends at this location have shown noticeable effects on pigeon pea yield across the Marathwada region. During this period, the mean maximum temperature reached up to 31.4 °C, while the minimum dropped to 19.0 °C. Mean annual rainfall was also variable, with the highest recorded value being 945.7 mm.
During the phenological assessment of pigeon pea, it was observed that the transition from emergence to the seedling stage required the longest duration, spanning approximately 25 to 29 days. In contrast, the shortest interval was recorded 5 to 8 days between sowing and emergence. However, climatic normals at Parbhani revealed that the highest cumulative rainfall was recorded in 28th SMW (1067.0 mm). The maximum average temperature (T_{max}) reached 37.3 °C in the 23rd SMW, while the minimum average temperature (T_{min}) dropped to 10.9 °C in the 51st SMW. Relative humidity levels also showed distinct patterns: the highest morning (RH-I) and evening (RH-II) relative xiv humidity values were recorded in the 38th SMW (89%) and 29th SMW (68%) respectively. Conversely, the lowest RH-I and RH-II values occurred in the 23rd SMW (73%) and 45th SMW (31%) respectively.

Keywords: Crop weather calendar, correlation of yield, phenological stages, pest of pigeonpea, weather parameters

Introduction
Pigeonpea (*Cajanus cajan* (L.) Millsp.), is an important grain legume belonging to the Fabaceae family, is a major pulse crop grown on a large scale in India. The potential yield of a particular crop under a given agro climatic condition greatly depends on the ideal sowing time. The dry matter accumulation and its partitioning into various organs are determined by the duration of crop growth and development, finally the crop yield. Crop duration can be used to determine the ideal time of sowing. Delayed sowing led to early maturity and makes the sharp decrease in yield compared to a timely sowing, which has a longer growth period and as a result, offers a chance to accumulate more biomass. (Nandini *et al.*, 2019) [7].
Sowing is a key agronomic practice that directly affects the potential yield of high-yielding varieties of crops by providing proper synchronization of vegetative and reproductive growth phases (Singh *et al.*, 2012) [9]. It further determines the accumulation potential of dry matter of the crop. Early planting increases more dry matter accumulation, whereas late planting may decrease biomass production and affect the yield adversely. Experiments have shown that sowing of pigeon pea (Behera *et al.*, 2018) [1] and chickpea (Niveditha *et al.*, 2022) [8] outside the recommended time results in significant reduction of grain yields.
Crop yield is regulated by a number of factors such as genotypes, climate, and soil type. Among these, meteorological parameters are a critical determinant of crop failure or success. It is quite self-evident that the yield of a particular crop or variety is dependent on the presence of optimal conditions for solar radiation, temperature, soil water, relative humidity, and other

environmental factors during different growth phases. Temperature is a critical meteorological parameter regulating plant development and growth. Serious issues in the process of attaining higher crop yields are moisture stress and inefficient photosynthetic performance. Photosynthesis, the plant growth process, is regulated by environmental parameters such as light intensity, humidity, temperature, and soil water. Among these, light is the most controlling factor regulating the process of photosynthesis. (Kenjle *et al.*, 1992) [3].

Materials and Methods

The present research work on "Preparation of a Crop Weather Calendar of Pigeon Pea (*Cajanus cajan* L. Millsp.)" was conducted in the Department of Agricultural Meteorology, VNMKV, Parbhani.

The climatic conditions are the indispensible topic in rainfed as well as irrigated farming system; the agricultural researches are planned according to the expected change in weather condition regionally. Without understanding the characterization and behavior of the changing weather parameters in coming days, how we will plan the research work and prepare crop weather calendar of soybean crop. Several studies on effect of increased temperature levels and incidence of pests on crop production endorse that there would be drastic reductions in crop yields. In agricultural production weather parameters play an important role. Soil and climate are two important resources which help in crop planning. For this purpose, the study of characteristics of temperature, rainfall, relative humidity, bright sunshine hours, wind speed and evaporation and its impact on crop phenology and incidence of pests is very important.

The methodologies and data that were used are described in this chapter under appropriate heads.

Structure of crop weather calendar

The crop weather calendar designed by AICRPAM is structured into three main sections, as illustrated in the figure. The top section presents climatic normals corresponding to the specific crop-growing season for the location. The middle section highlights the crop's phenological events, organized on a weekly timeline, along with the favourable climatic parameters necessary to achieve optimal or potential yield. The bottom section details the favorable weather conditions associated with pest development. Each component of the calendar is elaborated upon in the subsequent discussion. Crop weather calendar divided in three-part, Upper part, Middle part and Bottom part are pictorial represented in Fig. 1.1

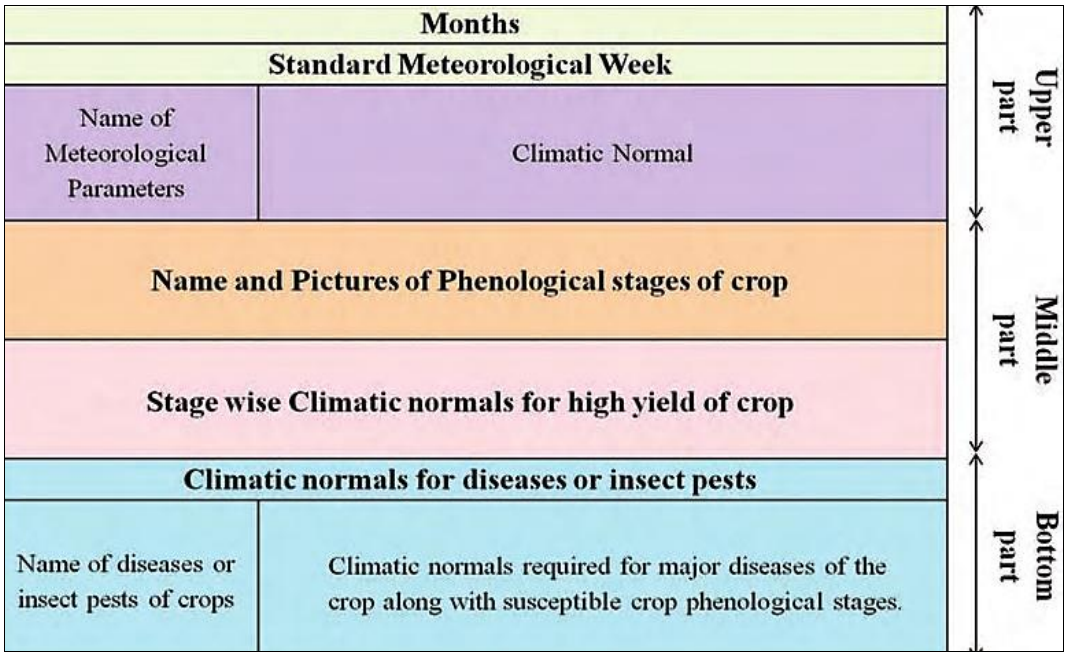

Fig 1.1: Structure of crop weather calendar

Crop weather calendars

Weather significantly affects crop production, especially in developing countries, due to increasing climatic variability and extreme events. To tackle these challenges, farmers can adopt adaptive management practices that align farming operations with weather data. In India, agriculture is vital and requires timely information on crop stages and weather patterns. Crop weather calendars like those from FAO and University of Kentucky help farmers plan sowing, harvesting, and other field activities month by month, improving efficiency and reducing costs.

Result and Discussion

To evaluate the crop-weather interactions over time, weather data corresponding to the pigeon pea growing seasons from 2015 to 2024 (23rd SMW to 02nd SMW) at Parbhani was categorized year-wise. This classification aimed to assess the crop's response to varying climatic conditions across different seasons. The associated agro-meteorological and crop performance data were compiled and presented in both tabular and graphical formats. The relevant data was presented in Table 1.1 and Fig 1.2.

Table 1.1: Mean of different phenophases of pigeon pea in relation to weather parameters at Parbhani location during 2015-2024

Phenophases	No. of days required to phenophases	Duration of crops at different sowing dates	Weather Parameters					
			Tmax (^{0}C)	Tmin (^{0}C)	RH-I (%)	RH-II (%)	BSS (hrs)	Total Rainfall (mm)
Sowing to Emergence (P_1)	5-8	D_1- 25th MW (155-160 days)	28.2-34.7	19.4-24.6	80-87	56-70	4.3-4.7	117.8-239
Emergence to Seedling stage (P_2)	25-29	D_2- 26th MW (170-190 days)	28.2-32.4	22.4-26.3	82-91	60-71	3.4-4.5	424-632.8
Seedling to Branching Stage (P_3)	8-14		28.9-32.5	20.4-22.5	84-92	62-67	4-5.5	368.4-434
Branching to Flowering Stage (P_4)	69-77		32.7-35.5	17.3-22.6	86-88	45-52	4.2-4.6	729.2-857.3
Flowering to Pod formation (P_5)	6-10	D_3- 27th MW (180-185 days)	30-34.3	16.7-21.3	76-84	40-47	5-8.5	31.9-73.1
Pod formation to Grain formation (P_6)	6-10		39.2-33.4	15.8-19.7	75-82	36-43	4.5-9	15.9-60
Grain formation to Maturity Stage (P_7)	34-40	D_4- 28th MW (160-175 days)	29.5-34.7	12.5-18.4	75-85	34-49	6.2-8.1	9.3-42.8

Crop weather calendar of Pigeonpea crop

Weather greatly influences agricultural productivity, especially in developing regions facing increasing climatic variability and extreme events like erratic rainfall, temperature shifts, and pest outbreaks. To maintain yields, farmers can adopt adaptive management practices and adjust crop environments.

In India, where agriculture is vital, effective planning requires accurate, timely, and localized data. Tools like crop-weather calendars help align farming activities like sowing, planting, harvesting with weekly weather conditions and agro-ecological zones. These calendars also guide seed rates, pest control strategies, and crop selection. Beyond daily operations, they support emergency preparedness and recovery planning after natural disasters, helping sustain agricultural productivity in a changing climate.

Recorded Parbhani location weather data during 2015-2024 of Pigeon pea crop: The weather data for Parbhani has been systematically organized year-wise for pigeon pea cultivation over the 2015-2024 period, corresponding to SMW 23rd through SMW 02nd. This ten-year dataset serves as a valuable resource for strategic agricultural planning, particularly in identifying opportunities for expanding priority crops, optimizing existing cropping systems, or introducing new varieties into agro climatically favorable zones within the region. The relevant meteorological parameters have been compiled in Table 1.2

Table 1.2: Yearly average weather data recorded different meteorological week during 2015-2024 (23rd SMW-02nd SMW) pigeon pea crop at Parbhani location

Year	T. Max ◦C	T. Min ◦C	R-H I %	R-H II %	Rainfall (mm)	BSS (hrs/day)	EVP (mm/day)	Wind (kmph)
2015	33.5	20.0	77	41	408.1	7.1	6.4	5.3
2016	31.1	18.1	82	50	1126.7	6.6	4.8	4.2
2017	30.5	18.0	81	50	991.5	6.7	4.6	3.9
2018	31.8	18.0	80	46	781.4	6.5	4.8	4.4
2019	31.5	19.5	82	52	967.4	6.1	4.5	4.5
2020	31.2	19.2	86	53	1008.4	6.2	3.8	3.5
2021	30.7	19.5	88	54	1604.4	5.6	4.0	3.8
2022	31.0	19.1	87	52	983.2	5.8	3.9	3.6
2023	31.7	19.4	84	48	705.1	5.9	4.5	3.0
2024	31.4	19.8	86	52	880.3	5.5	3.8	2.8
Mean	31.4	19.0	83	50	945.7	6.2	4.5	3.9

Upper part (Climatic normals)

The climatic normals for the Parbhani research centre were calculated for key weather parameters, including total weekly rainfall (mm), weekly maximum and minimum temperatures (°C), as well as morning (RH-I) and afternoon (RH-II) relative humidity (%). These values are organized by standard meteorological weeks and presented in the upper section of the crop-weather calendar. Figure 1.2 illustrates the compiled climatic normals specific to pigeon pea cultivation at the Parbhani location. The peak total rainfall was observed during the 28th meteorological week (106.7 mm), while the highest mean maximum and minimum temperatures were recorded in the 23rd week, reaching 38°C and 24°C, respectively. The maximum RH-I and RH-II occurred in the 38th (90%) and 29th (68%) weeks, whereas the lowest RH-I (73%) and RH-II (31%) were also noted during the 23rd SMW and 45th SMW. These observations are supported with the findings of Khobragade *et al.* (2016) [4-6].

Middle part (Phenological observation)

The sequential phenological stages of pigeon pea, spanning from sowing to harvest, are illustrated in Figure 1.2. The emergence to seedling phase exhibited the longest duration, requiring approximately 25 to 29 days. During crop development, the highest average maximum temperature (39.2°C-33.4°C) was recorded from pod formation to grain development, while the highest minimum temperature (22.4°C 26.3°C) occurred during the emergence to seedling stage. Relative humidity was also most elevated during the seedling to branching phase, with both RH-I and RH-II reaching their peak. Meanwhile, bright sunshine hours (BSS) were greatest during the pod formation stage to grain formation, suggesting enhanced solar exposure in the latter part of the season. Additionally, maximum rainfall was recorded during the branching to flowering stage, as depicted in Figure 1.2. These observations are consistent with the findings reported by Khobragade *et al.*, (2016) [4-6].

Bottom part

The crop weather calendar includes climatic normals relevant to the incidence of major pests and diseases affecting pigeon pea, along with the crop's phenological stages most susceptible to infestation. Notably, significant pest occurrences including Leaf webber, Gram podborer, Legume podborer, Plume moth and Podfly were primarily reported during the branching to flowering, flowering to pod formation, and pod formation to grain development phases. These infestations were closely

linked to irregular weather patterns and inadequate rainfall during the corresponding stages.

Between 36th SMW to 02nd SMW, pest populations showed distinct patterns of emergence and growth. *G. critica* appeared early in 36th SMW and peaked around 43rd SMW before sharply declining to zero by 49th SMW. *H. armigera* began its activity at 40th SMW and steadily increased, reaching its highest population at 51st SMW, suggesting sustained infestation. *M. vitrata* emerged from 39th SMW and grew steadily through 52nd SMW, indicating consistent presence. *E. atomosa* first appeared in 43rd SMW and followed a gradual upward trend through 52nd SMW. Most notably, *M. obusta* showed no activity until 43rd SMW but surged dramatically thereafter, reaching peak levels by 02nd SMW. Overall, pest pressure intensified notably from 43rd SMW onward, with *M. obusta* demonstrating the most concerning and persistent infestation, underscoring the critical need for targeted pest management during this period. These observations are consistent with the findings reported by Ugale *et al.* (2024) [10].

Conclusions: During 2015 to 2024, meteorological parameters were found to significantly influence the phenological stages from sowing to maturity (P_1-P_7) of pigeon pea. A strong positive correlation was observed between maximum temperature (T_{max}) and the later growth stages, particularly P_5 (flowering to pod formation) and P_6 (pod formation to grain formation), indicating that elevated temperatures may accelerate physiological maturation. Minimum temperature (T_{min}) demonstrated a positive impact across most growth stages, especially during the initial and terminal phases, underscoring its crucial role in both crop establishment and reproductive development.

Temperature and rainfall were identified as the most influential climatic variables affecting the developmental stages of the crop. In addition, parameters such as humidity, wind speed, evaporation, and bright sunshine hours played significant yet stage-specific roles in modulating crop growth. These findings highlight the necessity of aligning crop management strategies with the prevailing agroclimatic conditions at each phenological phase to optimize productivity and resource efficiency.

As a part of crop weather calendar, the crop growing seasons from 2015 to 2024, Parbhani exhibited notable variability in key weather parameters. The highest cumulative rainfall was recorded at 1604.4 mm in year 2021, while the lowest was 408.1 mm in year 2015, highlighting substantial differences in seasonal precipitation. The average maximum temperature ranged from 30.5°C to 33.5°C, and the minimum temperature varied between 18.0 °C and 20.0 °C. Relative humidity during morning hours (RH-I) showed a wide span from 77% to 88%, whereas afternoon values (RH-II) ranged from 41% to 54%. Bright sunshine hours fluctuated between 5.5 and 7.1 hours, indicating variable solar exposure across growing periods.

CROP WEATHER CALENDAR

CROP NAME : PIGEON PEA | **DURATION: LONG (150-185 days)** | **STATE : MAHARASHTRA** | **DISTRICT : PARBHANI**

	MONTH	JUNE				JULY				AUG					SEPT				OCT				NOV				DEC					JAN	
	Std.week / Parameter	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2
Climatic Normals	Rain (mm)	48.4	58.0	32.4	34.7	41.0	106.7	56.2	37.1	26.3	21.3	37.2	58.2	45.1	63.3	47.0	65.4	44.4	28.4	38.1	30.4	11.4	1.3	0.0	0.0	0.1	12.3	0.6	0.1	0.0	0.4	1.3	0.0
	Tmax (^{0}C)	37.3	35.5	34.3	33.2	32.9	31.0	31.2	30.5	31.1	31.1	30.4	30.8	29.8	29.4	30.9	31.3	31.7	32.9	32.8	32.6	32.3	31.8	31.9	31.5	31.0	30.0	30.0	30.0	29.1	28.9	29.4	29.5
	Tmin (^{0}C)	24.1	23.7	23.8	23.4	23.4	23.0	22.9	22.5	22.6	22.5	22.2	20.7	20.8	21.8	21.9	22.0	21.6	21.3	20.5	19.5	17.2	16.0	14.6	14.4	15.1	13.6	14.6	13.9	11.0	11.1	11.6	12.1
	BSS (hr/day)	6.5	6.9	6.0	4.9	4.7	3.4	4.0	3.3	4.2	3.7	4.0	5.9	5.8	5.7	5.2	4.6	5.8	7.4	7.2	7.7	8.0	8.6	8.0	8.1	7.7	7.0	6.7	7.9	7.8	7.1	7.1	7.6
	RHm (%)	73	78	79	84	82	87	87	87	85	86	88	88	88	86	81	90	88	86	86	83	82	81	80	80	82	81	81	82	82	81	82	80
	RHe (%)	39	48	53	58	58	67	68	67	65	63	67	62	62	64	66	65	60	53	49	45	35	35	31	34	37	37	40	35	31	33	36	35
	EVP (mm)	8.1	6.8	6.5	4.9	5.0	4.1	4.2	3.7	4.0	4.4	4.0	4.0	4.2	4.1	3.6	3.7	4.1	4.8	4.8	4.8	4.5	4.7	4.6	4.5	4.3	4.1	3.9	4.2	4.1	3.6	3.7	4.1
	WS (kmph)	6.2	6.6	6.1	5.2	5.8	5.8	4.8	4.8	5.1	4.8	4.3	4.3	4.0	3.9	3.8	3.6	3.1	2.9	2.5	2.7	2.2	2.9	2.6	3.0	2.9	2.9	3.2	3.2	3.1	2.9	3.0	3.2

Phenophases	Emergence	Seedling	Branching	Flowering	Pod formation	Grain formation	Maturity
Duration (Days)	5--8	25-29	8--14	69-77	6--10	6--10	34-40
Phenophase wise weather for better yield: Tmax (^{0}C)	28.2-34.7	28.2-32.4	28.9-32.5	32.7-35.5	30.0-34.3	39.2-33.4	29.5-34.7
Tmin (^{0}C)	19.4-24.6	22.4-26.3	20.4-22.5	17.3-22.6	16.7-21.3	15.8-19.7	12.5-18.4
RHm (%)	80-87	82-91	84-92	86-88	76-84	75-82	78-85
RHe (%)	56-70	60-71	62-67	45-52	40-47	36-43	34-49
BSS (hrs/day)	4.3-4.7	3.4-4.5	4-5.5	4.2-4.6	5.0-8.5	4.5-9.0	6.2-8.1
Rain(mm/wk)	39.3-79.7	141.3-210.9	122.8-144.7	243.1-285.8	10.6-24.4	5.3-22.5	3.0-23.3
EVP(mm/wk)	3.59-8.13	3.7-5	3.2-4.4	3.6-4.2	3.8-4.8	3.5-4.7	3.8-6.4
WS (kmph)	2.21-6.56	3.1-8	2.6-6.4	2.1-6.5	1.7-4.3	2.6-3.9	3.1-4.2
Favourable Weather for pest Incidence: Pests							
Leaf webber							
Gram podborer							
Legume podborer							
Plume moth	Tmax:30.6-33.1°C, Tmin:13.7-21.8°C	Tmax:29.0-33.1°C, Tmin:11.2-21.8°C	Tmax:28.6-33.1 °C, Tmin: 13.1-22.3 °C	Tmax: 28.6-32.8°C, Tmin: 13.3-21.5 °C	Tmax:28.6-33.1°C,Tmin:11.2-21.5°C		
Pod fly	RHm:83.8-93.0%, Rhe:30.3-72%	RHm:84.3-93%, Rhe:29.5-66.5%	RHm:84.3-91.5%, Rhe:39.5-66.0%	RHm:86.3-89.5%,Rhe:29.5-50.8%	RHm:83.8-89.5%,Rhe:29.5-48.8%		

Fig 1.3: Crop Weather Calendar of Pigeon pea crop under parbhani location during 2015-2024

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