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Correlation between weather parameters and different Phenophases of Soybean (*Glycine max*. [L] Mirrll.) With seed yield

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Abstract
A study was conducted to assess the impact of meteorological parameters on soybean yield. Soybean's introduction led to higher cropping intensities, which increased profitability per acre. Soybean is and will remain an important rainfed oilseed crop in India, with growth, development, and yield performance all being affected by the weather at different stages of the crop's life cycle. However, only a few of these characteristics have a major impact on crop growth and output. To better understand the relationship between weather parameters and soybean yield, the agrometeorological indices and soybean yield were determined. Correlation coefficients also indicated that temperature seems to have a significant impact on seed yield. Thermal indices such as GDD, PTU, and HTU, as utilized in this study, must be considered not only in terms of high or low values of the prevailing temperature during the specific phenological stages, but also in terms of temperature taken in conjunction with the duration of the specific phase. The maximum temperature was positively connected with soybean seed yield at the P1, P3, P4, P5, and P8 stages of MAUS-158, but negatively correlated at the P2 and P6, P7 stages. The maximum temperature was positively connected with soybean seed yield at the P3, P4, P5, and P8 stages of MAUS-71, while it was adversely correlated at the P2 and P6, P9 stages. The highest temperature was positively connected with soybean seed yield at the P3, P4, P5, and P8 stages and negatively correlated at the P2 and P6, P9 stages of JS-335.

Keywords: Soybean yield, weather parameter, correlation, MAUS-71, GDD, PTU

Introduction

Soybean (*Glycine max* L. Merril) is the world's most significant seed legume, accounting for 25% of worldwide edible oil and almost two-thirds of global protein concentrate for livestock feeding. (Agarwal *et al*., 2013) [1]. It is a leguminous pulse and oil seed crop grown in India's tropical and subtropical regions. Because of its nutritional and physiological benefits, soybean is known across the world as the "wonder crop" of the twentieth century. The crop is grown in warm areas such as the tropics, subtropics, and temperate zones. Soybean is resistant to both cold and high temperatures, but growth rates reduce above 35 °C and below 18 °C. Temperatures between 20 and 30 degrees Celsius are ideal for soybean production, with temperatures beyond 35 degrees Celsius considered inhibitive. The ideal soil temperature for germination and early seedling growth is 25 to 30o C. For a profitable crop, soybean requires 400 to 500 mm of water every season (Nimje, 2017) [6]. Soybeans can withstand minor waterlogging, but seed weathering is a severe issue throughout the wet season It is a short-season and thermo-sensitive crop, and its yield response varies with variety and temperature. It can be cultivated successfully in both kharif and summer when suitable irrigation facilities are available (Kumar *et al*., 2008) [3]. The primary weather variable influencing plant life is temperature (Bobade *et al*., 2020) [2] Soybean is generally a short-day plant, however its sensitivity to day length varies depending on variety and temperature, and cultivated cultivars are only adapted to a relatively small latitude variation. The length of the day affects the rate of crop development. Increased day duration may cause blooming to be delayed and larger plants with more nodes in short day variants Short days promote flowering, especially for late mature cultivars (Misal & Deshmukh, 2020) [4]. Furthermore, different climatic conditions have distinct effects on crop growth and development. As a result, it was expected to gain insight into the effect of various weather characteristics and therefore agro-meteorological indices on soybean crop output, as well as to determine the important phenophases during which soybean crop was most responsive to the effect of certain weather parameters (Kumar *et al*., 2008) [3]. Rainfall reduction showed a detrimental impact on it.

This effect was enhanced by an increase in temperature, resulting in a decrease in soybean production. Raising the temperature while decreasing rainfall by 10% reduced soybean production by 10%. Yet, increases in temperature and rainfall did not result in favorable soybean growth. (2017) (Mohanty *et al*. 2017) [5]. The purpose of this study was to determine the correlation coefficients between weather parameters and distinct phenophases of soybean (*Glycine max*. [L] Mirrll) and seed yield.

Materials and Methods

Sites, climate, soil data

The experiment was carried out in the experimental farm of the Department of Agricultural Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, during the Kharif season of 2019 (India). The experimental site (Parbhani) is located at 76046 E longitude, 19016 N latitude, and 409 m altitude above mean sea level (MSL). The field's topography was consistent and level. The soil had a medium black clayey texture with a uniform depth of around one meter. On a yearly basis, the climate of Marathwada may be described as semi-arid. The region has hot and dry summers, chilly and dry winters, and wet humidity with medium rainfall during the monsoon season Weather data for the experiment period in 2019 were collected at the Meteorological Observatory, All India Coordinated Project on Agrometeorology, Vasantrao Naik Marathwada Agricultural University, Parbhani. The experimental plot's soil was vertisol (Medium dark), clayey in texture, and had a constant depth of 1.20 m.

Correlation studies of grain and total biomass yield with respect to various weather data types as well as agrometeorological indices were carried out phenophasewise of soybean using the methodology described by Gomez and Gomez(1984) for the crop sown on the first (D1), second (D2), third (D3), and fourth (D4) dates of sowing. The phenological observations, i.e. no. of days required for different phenological stages.

Phenological Stages	Description
P1	Sowing to emergence
P2	Emergence to seedling
P3	Seedling to branching
P4	Branching to flowering
P5	Flowering to pod formation
P6	Pod formation to grain formatiom
P7	Grain formation to pod development
P8	Pod development to pod containing full size grain
P9	Pod containing full size grain to dough stage
P10	Dough stage to maturity

The phenological data collected from the soybean crop were sorted and analyzed based on its phenological stages and varied dates of sowing D1 (26MW), D2 (27MW), D3 (28MW), and D4 (29MW).

Results and Discussions

Weather parameters such as (RF), bright sunshine hours (BSS), maximum (T max.), minimum (T min.), and mean (T mean) temperatures, morning (RH), afternoon (RH), and mean (RH mean) relative humidities, and agro-meteorological indices such as accumulated growing degree days (Acu. GDD), accumulated photo thermal unit (Accu. PTU), and accumulated helio-thermal unit (Accu (Kumar *et al*., 2008) [3]. The performance of seed and Stover yield was evaluated phase by phase in terms of seed yield and total biomass, together with the corresponding weather parameters and agro-meteorological indices (Shah and Hanta, 1989) [7].

Agro meteorological indices

Growing Degree Days (GDD)

Table 1: Phenophasewise GDD required for different dates of sowing of Soybean during *Kharif* 2019

Treatment	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P10	Total
D_1: 26 SMW	235.4	552.3	86.7	143.6	147	178.35	442.1	402.1	410.2	219.4	2817.2
D_2: 27 SMW	157.2	562.8	90.6	146.9	177.5	234.9	428.6	384.7	353.4	211.9	2748.8
D_3: 28 SMW	192.1	261.7	94.7	177.5	153.7	228.2	453.1	386	357.5	139.4	2444
D_4: 29 SMW	189.5	532.1	97.2	153.7	181.5	219.4	432.2	380.6	315.1	140.1	2641.3
Mean	193.6	477.2	92.3	155.4	165	215.2	439	388.4	359.0	177.7	266.3

Date of sowing D1 (SMW 26) had a higher heat load (i.e. 2817.250C day) than the other treatments, which could be attributed to the maximum air temperature at sowing time. D3 (SMW 28) lowest heat load (i.e. 24440C day) heat unit necessary for obtaining various phenophases in D4 (SMW 29) date of sowing due to temperature influence and delayed sowing during the crop growth season.

Helio-thermal Units (HTU)

Table 2: Phenophasewise HTU required for different dates of sowing of Soybean during *Kharif* 2019

Treatment	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P10	Total
D_1: 26 SMW	675.7	3579.2	0.0	244.1	563	957.73	2334.2	1527.9	2916.5	1575.3	14373.9
D_2: 27 SMW	709.2	2999.9	140.50	367.2	1006.7	1515.1	1637.4	2038.9	2537.4	1258.9	14211.4
D_3: 28 SMW	1613.6	837.6	246.3	1012	1014.4	1346.6	1495.3	2817.8	2395.2	473.9	13253.1
D_4: 29 SMW	1288.6	1383.3	456.8	1075.9	1869.4	623.2	2117.7	2740.3	1827.2	686.5	14069.1
Mean	1071.8	2200.1	210.9	674.82	1113.4	1110.7	1896.2	2281.3	2419.1	998.7	1397.6

The mean helio-thermal units measured in sowing dates (D1 to D4) ranged from 13253.19 to 14373.810C day hour. The helio-thermal units were greater on the first date of sowing, 14373.810C day hour in D1 (SMW 26). Due to temperature variations and bright sunshine hours during the crop growing season, D3 (SMW 28) had the lowest HTU, 13253.190C day hour, compared to the other treatments.

Photo-thermal Units (PTU)

Table 3: Phenophasewise PTU required for different dates of sowing of Soybean during *Kharif* 2019

Treatment	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P10	Total
D_1: 26 SMW	2354.5	5523.5	867	1436	1470	1783.5	4421	4021	4102	2194	28172.5
D_2: 27 SMW	1572.5	5628.5	906.5	1469	1775.5	2349	4286.5	3847	3534	2119.5	27488
D_3: 28 SMW	1921	2617	947.5	1775.5	1537	2282	4531	3860	3575	1394	24440
D_4: 29 SMW	1895	5320.5	972	1537	1815	2194.5	4322	3806	3150.5	1401	26413.5
Mean	1935.7	4772.3	923.2	1554.2	1649.3	2152.2	4390	3883.5	3590.3	1777.1	2662.7

Date of sowing D_1 (SMW 26) indicated more heat load (i.e. 28172.5 ^{0}C day) than rest of the treatments it may be due to maximum air temperature prevailed at sowing time. Date of sowing D_3 (SMW 28) lowest heat load (i.e. 24440 ^{0}C day) heat unit required for attaining various phenophases. In D_3 (SMW 28) date of sowing due to effect of temperature and delayed sowing during the crop growing season. It is cleared that, when temperature of air was maximum then definitely it affects PTU of soybean crop. The highest mean value i.e. 4772.3 ^{0}C day was recorded in phenophases P_2 of all date of sowing.

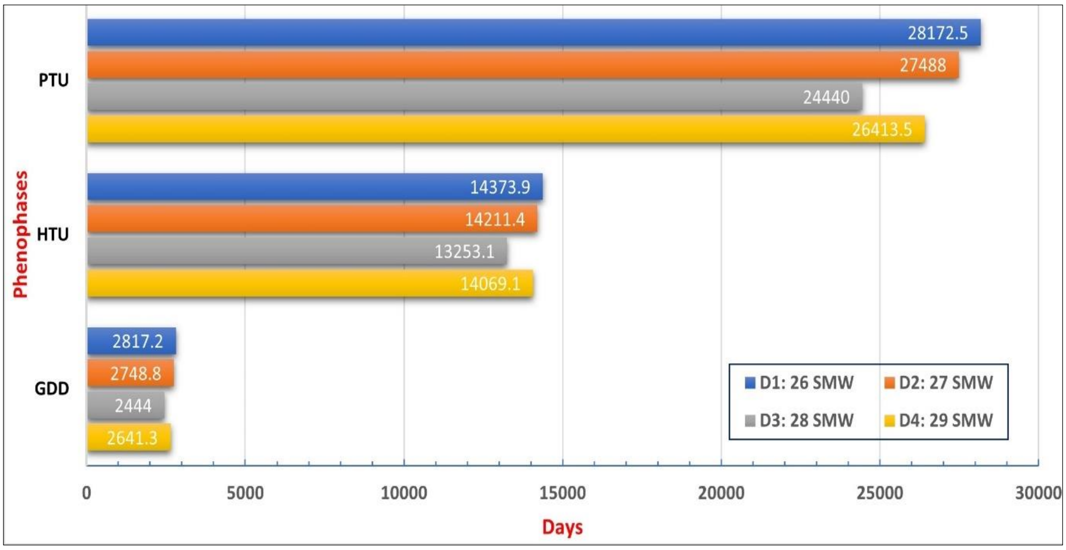

Fig 1: Total of phenological stages

Correlation studies

Table 4: Correlation between weather parameters and different Phenophases of Soybean with seed yield V_1 (MAUS-71)

Weather Parameters	Phenological stages of Soybean									
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Rainfall	-0.811**	0.569*	-0.322	-0.597*	-0.657*	0.517	0.753**	-0.701*	0.731**	0.281
Rainyday	-0.660*	0.45	-0.476	-0.809**	-0.632*	0.512	0.875**	-0.870**	0.031	0.389
TMax	0.26	-0.683*	0.774**	0.667*	0.721**	-0.828**	-0.368	0.598	-0.580*	-0.164
TMin	0.872**	-0.820**	-0.147	0.181	-0.185	-0.16	-0.385	-0.635*	-0.563	0.128
RH-I	0.469	0.154	-0.907**	-0.557	-0.521	0.555	0.893**	-0.05	-0.38	-0.587*
RH-II	-0.386	0.664*	-0.629*	-0.696*	-0.819**	0.781**	0.479	-0.706*	-0.441	0.51
EVP	0.565	-0.728**	0.740**	0.726**	0.826**	-0.659*	-0.583*	0.682*	0.132	-0.654*
BSS	0.37	-0.677*	0.874**	0.678*	0.915**	-0.716**	0.087	0.597	-0.796**	-0.279
WV	-0.783**	0.647*	-0.801**	-0.155	-0.604*	0.155	-0.914**	-0.647*	0.591*	0.860**

Table 5: Correlation between weather parameters and different Phenophases of Soybean with seed yield V_2 (MAUS-158)

Weather Parameters	Phenological stages of Soybean									
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Rainfall	-0.971**	0.821**	-0.514	-0.827**	-0.869**	0.741**	0.945**	-0.917**	0.529	0.575*
Rainy day	-0.844**	0.760**	-0.733**	-0.959**	-0.883**	0.679*	0.983**	-0.955**	-0.280	0.618*
T Max	0.615*	-0.905**	0.927**	0.894**	0.924**	-0.877**	-0.633*	0.862**	-0.834**	-0.412
T Min	0.837**	-0.974**	0.044	-0.214	-0.003	-0.159	0.001	-0.668*	-0.836**	0.304
RH-I	0.125	0.561	-0.990**	-0.737**	-0.778**	0.752**	0.992**	0.082	-0.710**	-0.227
RH-II	-0.707*	0.896**	-0.827**	-0.920**	-0.978**	0.767**	0.783**	-0.912**	-0.755**	0.796**
EVP	0.813**	-0.931**	0.915**	0.926**	0.969**	-0.565	-0.825**	0.894**	0.505	-0.881**
BSS	0.700*	-0.894**	0.975**	0.870**	0.964**	-0.613*	-0.226	0.860**	-0.830**	-0.630*
WV	-0.788**	0.364	-0.899**	-0.524	-0.460	0.149	-0.949**	-0.892**	0.630*	0.907**

Table 6: Correlation between weather parameters and different Phenophases of Soybean with seed yield V_3 (JS - 335)

Weather Parameters	Phenological stages of Soybean									
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Rainfall	-0.948**	0.697*	-0.313	-0.696*	-0.881**	0.580*	0.921**	-0.831**	0.456	0.607*
Rainy day	-0.886**	0.703*	-0.580*	-0.876**	-0.812**	0.501	0.985**	-0.869**	-0.33	0.690*
T Max	0.552	-0.813**	0.824**	0.798**	0.909**	-0.763**	-0.678*	0.803**	-0.729**	-0.207
T Min	0.936**	-0.910**	0.177	-0.138	-0.223	0.041	-0.107	-0.506	-0.742**	0.087
RH-I	0.123	0.18	-0.935**	-0.570*	-0.790**	0.590*	0.940**	0.241	-0.629*	-0.299
RH-II	-0.666*	0.806**	-0.687*	-0.864**	-0.933**	0.641**	0.711**	-0.815**	-0.683*	0.688*
EVP	0.820**	-0.850**	0.807**	0.836**	0.894**	-0.443	-0.832**	0.787**	0.438	-0.774**
BSS	0.598*	-0.791**	0.903**	0.744**	0.894**	-0.494	-0.277	0.775**	-0.706*	-0.542
WV	-0.661*	0.33	-0.784**	-0.418	-0.642*	0.349	-0.875**	-0.837**	0.46	0.974**

Rainfall and rainy days were positively correlated with soybean seed yield at P2 and P6, P7, P8, P10 stages, but negatively correlated at P1 and P4, P5 stages of the MAUS-158 variety. Rainfall and rainy days were positively connected with soybean seed output at P2 and P7, P9 stages, but negatively correlated at P1 and P4, P5, P8 stages of the MAUS-71 variety. Rainfall and rainy days were positively connected with soybean seed yield at P2, P6, P7, and P10 stages, but negatively correlated at P1 and P4, P5, and P8 stages of the JS-335 variety. The maximum temperature was positively correlated with seed yield of soybean at P_1, P_3 and P_4,P_5,P_8 stages however it was negatively correlated at P_2 and P_6,P_7 stages of MAUS-158. The maximum temperature was positively correlated with seed yield of soybean at P_3, P_4, P_5, P_8 stages however it was negatively correlated at P_2 and P_6,P_9 stages of MAUS-71. The maximum temperature was positively correlated with seed yield of soybean at P_3, P_4, P_5, P_8 stages however it was negatively correlated at P_2 and P_6,P_9 stages of JS-335. The minimum temperature was positively correlated with seed yield of soybean at P_1 stages however it was negatively correlated at P_2 and P_8, P_9 stages of MAUS-158. The minimum temperature was positively correlated with seed yield of soybean at P_1 stages however it was negatively correlated at P_2 and P_8, stages of MAUS-71. The minimum temperature was positively correlated with seed yield of soybean at P_1 stages however it was negatively correlated at P_2 and P_9, stages of JS- 335. The RH-I was positively correlated with soybean yield at $P_6$and P_7 stages and RH-II was positively correlated with soybean yield at P_2, P_6, P_7,P_{10} however RH-I was negatively correlated at P_3, P_4 and P_5, P_9 stages and RH-II was negatively correlated at P_1, P_3 and P_4, P_5, P_8,P_9 stages of MAUS-158. The RH-I was positively correlated with soybean yield at P_7 stages and RH-II was positively correlated with soybean yield at P_6 however RH-I was negatively correlated at P_3 and P_{10} stages and RH-II was negatively correlated at P_3 and P_4, P_5, P_8 stages of MAUS-71. The RH-I was positively correlated with soybean yield at P_6 and P_7 stages and RH-II was positively correlated with soybean yield at P_2, P_6, P_7, P_{10} however RH-I was negatively correlated at P_3 and P_4,P_5,P_9 stages and RH-II was negatively correlated at P_1 and P_3, P_4, P_5, P_8,P_9 stages of JS-335. The evaporation was positively correlated with soybean yield at P_1, and P_4, P_5,P_8 stages however it was negatively correlated at P_2 and P_7,P_{10} stages of MAUS- 158. The evaporation was positively correlated with soybean yield at P_3, and P_4, P_5, P_8 stages however it was negatively correlated at P_2 and P_7,P_{10} stages of MAUS-71. The evaporation was positively correlated with soybean yield at P_1, and P_3 P_4,P_5,P_8 stages however it was negatively correlated at P_2 and P_7,P_{10} stages of JS-335. The B.S.S was positively correlated with soybean yield at P_1, and P_3,P_4, P_5, P_8 stages however it was negatively correlated at P_2 and P_6, P_9, P_{10} stage MAUS- 158. The B.S.S was positively correlated with cowpea yield at P_3, and P_4,P_5 stages however it was negatively correlated at P_2 and P_9, stage MAUS-71. The B.S.S was positively correlated with cowpea yield at P_1, and P_3,P_4, P_5,P_8 stages however it was negatively correlated at P_2 stage JS-335. The wind velocity was positively correlated with soybean yield at P_9 and P_{10} stages however it was negatively correlated at P_1 and P_3, P_7, P_8 stage MAUS-158. The wind velocity was positively correlated with soybean yield at P_2 and P_9, P_{10} stages however it was negatively correlated at P_1 and P_3, P_5, P_7,P_8 stage MAUS- 71. The wind velocity was positively correlated with soybean yield at P_{10} stages however it was negatively correlated at P_1 and P_3, P_5, P_7,P_8 stage MAUS-71

Conclusion
Soybean sown in D1 required the highest growing degree-days and hydrothermal units as D1 sowing date. The Rainfall was positively correlated with P2, P6, P7, P9, P10; T_{min} and T_{max} was positively correlated with P1, P3, P4, P5, P8; RH-I and RH-II was positively correlated with P1, P2, P6, P7, P8; the wind velocity was positively correlated at P2, P6, P7, and P10 stages of soybean crop; and lastly BSS and Evaporation was positively correlated at all growth stages except P2, P6, P9 and P10 of different cultivars *viz.*, V1 (MAUS-71), V2 (MAUS-158), V3 (JS-335) of soybean crop.

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