

Original Research Article

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Impact of Weather Parameters on Yield of *Kharif* Sunflower (*Helianthus annuus* L.) under Different Growing Environments in Scarcity Zone of Maharashtra

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ABSTRACT

Present investigation entitled “Impact of weather parameters on yield of *kharif* sunflower (*Helianthus annuus* L.) Under different growing environments in scarcity zone of Maharashtra.” was carried out during 2013-17 at Zonal Agricultural Research Station, Solapur, Maharashtra State (India). The experiment was conducted in split plot design with three replications. Nine treatment combinations were formed considering different cultivars viz., V₁ Bhanu, V₂ MSFH-1 and V₃ Phule Bhaskar and sowing windows viz., (S₁) 2nd fortnight of June (25th-June), (S₂)- 2nd fortnight of July (27th-July) S₃-2nd fortnight of August (24th-August). Among the three pearl millet sowing window crop sown in second fortnight of July (S₂) produced significantly highest grain yield (1708.2 kg ha⁻¹) and total monetary returns (56320 kg ha⁻¹), (CUM) (320 mm), (MUE) (5.3 Kg ha⁻¹ mm), (GDD) (1042⁰ days), total dry matter (400.8 g m⁻²), LAI and RUE July (1.31 & 1.63 g MJ⁻¹) than other dates of sowing. Among the genotypes Phule Bhaskar produced significantly higher grain yield (1446.8 kg ha⁻¹), total monetary returns (Rs. 47590 ha⁻¹), CUM (293.1 mm), MUE (4.8 Kg ha⁻¹ mm), mean number of days to attain physiological stages (92 days), GDD (846⁰ days), mean total dry matter (404.1 g m⁻²) than other cultivars. The correlation study revealed that the wind speed had significant positive correlation at emergence phase (P₁) and 3 leaf stage (P₂). Tmax had significant positive influence and RH-I, RH-II and RF has significant negative influence at button phase (P₃).

Keywords

Kharif sunflower,
Sowing windows,
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Introduction

Oil seed crops occupy an important position next to food grains in Indian economy. The oil not only forms an essential part in human diet but also serves as an important raw material for manufacture of various products like flavour enhancers, lubricants etc. Sunflower (*Helianthus annuus* L.) is one of the most popular members of the family

Asteraceae and is one of the world's most important sources of vegetable oil and It is a rich source of edible oil (40-52%) having anticholesterol properties (Joksimovic *et al.*, 2006). The native of the sunflower is reported to be Southern parts of USA and Mexico. Sunflower (*Helianthus annuus*, L), is an important oil crop worldwide. Moreover, it's hardy and superior to sorghum (*Sorghum bicolor* L) in drought tolerance (Rachid *et al.*,

1993). Under dryland conditions, sunflower extracts water from deeper soil profile to enable the crop tolerate prolonged dry periods (Unger *et al.*, 1976; Meinke *et al.*, 1993). Also, crop is well adopted by the farming community because of its desirable attributes such as short duration, photoperiod insensitivity, adaptability to wide range of soil and climatic conditions, drought tolerance, lower seed rate, higher seed multiplication ratio and high quality of edible oil (45-50%) (Reddy *et al.*, 2007).

Materials and Methods

The study was conducted at research farm of Zonal Agricultural Research Station, Solapur, Maharashtra State (India) during in year 2013-2017 in the *Kharif* season. The area is positioned at 75° 65' N latitude 75° 90'E longitude and at the altitude of 483.6 meters above the sea level.

The experiment was conducted in split plot design with three replications. Nine treatment combinations were formed considering different cultivars viz., V₁ Bhanu, V₂ MSFH-1 and V₃ Phule Bhaskar and sowing windows viz., (S₁) 2nd fortnight of June (25th-June), (S₂)- 2nd fortnight of July (27th-July) S₃-2nd fortnight of August (24th-August). The soil comes under the vertisol (medium black) clayey loam in texture and slightly alkaline (pH-7.4) in nature and having the depth up to 90 cm.

The monsoon lasts from June to the end of September, with moderate rainfall. It has an average rainfall of about of 545 mm per year. The annual maximum and minimum temperature ranged between 25.0 to 43.2⁰C and 7.3 to 27.1⁰ C, respectively. The gross and net plot sizes were 6.0 x 4.5m² and 4.2 x 3.6 m², respectively. All the cultivars are were dibbled as per different sowing windows at a spacing of 45 cm x 20cm.

Results and Discussion

Agronomical studies

The crop sown in second fortnight of July (S₂) produced significantly highest grain yield (1708.2 kg ha⁻¹) and total monetary returns (56320 kg ha⁻¹) than other dates of sowing. These findings are in confirmative with those reported by Keshta *et al.*, (2006), Dhanasekar *et al.*, (2012) and Khan *et al.*, (2016). In general pearl millet can be sown up to second fortnight of August (S₃). It was revealed from that the crop sown at second fortnight of July (S₂) produced significantly higher grain yield and total monetary returns with high degree of sustainability. These results are in close agreement to the findings of Kawade *et al.*, (2018). It might be due to crop sown at second fortnight of July (S₂) gets sufficient period for its biological and reproductive development and ultimately resulted into higher grain yield and total monetary returns. It also indicates that crop sown at second fortnight of June (S₁) get sufficient uniform availability of moisture during its life span helps for better yield and monetary benefits. However among the genotypes Phule Bhaskar produced significantly higher grain yield (1446.8 kg ha⁻¹) and total monetary returns (Rs. 47590 ha⁻¹). This indicates sustainability of Phule Bhaskar variety over other varieties. This might be due to short duration life span of Phule Bhaskar than other varieties and at reproductive stage MSFH-17 and Bhanu might be faced moisture stress condition (Table 1 and 2).

Meteorological studies

The mean consumptive use of moisture (CUM) (320 mm) and mean moisture use efficiency (MUE) (5.3 Kg ha⁻¹ mm) was significantly higher recorded by crop sown in second fortnight of July (S₂) over rest of the

sowing windows (Table 3). It indicates that early and delay in sowing of crops results in recording low value of CUM and MUE. This might be due to July sown crop gets sufficient period to utilize available soil moisture along with good weather for grain production. Being thermo-sensitive and short day plant, sowing time affect phenology of the crop from adoption to the time of maturity (Kumar and Badiyala, 2005). Phule Bhaskar recorded highest mean value of CUM (293.1 mm) and MUE (4.8 Kg ha⁻¹ mm). This indicates that the Phule Bhaskar variety utilized the moisture most efficiently for productions of grains. The mean number of days required to attain the physiological maturity stages recorded higher in July sown crop (S₂) (Table 4). This might be due to more favorable conditions prevailed in case early sown crop and vice versa. Phule Bhaskar required more mean number of days to attain physiological stages (92 days) than MSFH-17 (84 days) and Bhanu (78 days). This indicates Phule Bhaskar variety required more number of days to attain physiological maturity than other varieties during *kharif* season under dryland conditions.

The growing degree days (GDD), the function of maximum, minimum and base temperature were presented in Table 5. The crop sown in second fortnight of July (S₂) recorded highest mean value of growing degree days (GDD) (1042⁰ days) than other windows of sowing. It indicates that as a GDD is a function of temperature, during July (S₂) sown crop might be grown under high temperature condition and hence recorded highest values of GDD. Further, it is seen that S₂ sown crop required more growing degree days to attain physiological maturity. Sattar *et al.*, 2017 revealed that variation in phenophase duration caused by changes of sowing dates, which led to early or delayed fulfillment of thermal requirements to attain a particular phenological stage in soybean crop. However,

among the varieties the values of mean GDD were higher in Phule Bhaskar (846⁰ days) followed by MSFH-17 (868⁰ days) and Bhanu (801⁰ days) variety. This is due to more duration required by S₂ sown crop and Phule Bhaskar variety. Further, it was also noticed that the early sown crop not received fairly good amount of rainfall during its growth period due to which soil moisture available was less, however, late sown crop favours due to moisture availability during flowering and grain filling stage which resulted in more duration required for maturity and good yield. In short the second fortnight of July (S₂) sown crop required more number of days to attain various growth stages. This is due to existence of favourable condition for crop growth and development. This is because the GDD which is function of temperature which in turn is a function of bright sunshine hours.

The mean maximum values of total dry matter were recorded by S₂ sown crop i.e. 400.8 g m⁻² over rest of the sowing windows. Data revealed that as the delay in sowing of *kharif* sunflower there is considerable reduction in mean total dry matter. Among the genotype Phule Bhaskar variety recorded highest values of mean total dry matter (404.1 g m⁻²) in almost all the growth stage than the other varieties (Table 6). This indicates that the Phule Bhaskar utilized more efficiently moisture, light and temperature and produced maximum total dry matter by maximum solar radiation interception.

The highest mean values of LAI and RUE recorded by the crop sown in second fortnight of July (1.31 & 1.63 g MJ⁻¹) (Table 7 & 8) at 50 per cent flowering stage in almost all the sowing dates and genotypes. It was also revealed that with delayed sowing recorded low mean values of LAI and RUE. This indicated that the rate of conversion of light *i.e.* photosynthetically active radiation (PAR) was considerably high at 50 per cent

flowering stage, thereafter the conversion rate was declined due to ageing of leaves. Among the sowing windows maximum mean RUE values were higher in July sown crop than late sown crop. Further, it was seen that Phule Bhaskar showed higher values of RUE than MSFH-17 and Bhanu variety for conversion of light into dry matter in all the dates of sowing (Table 7 & 8). In short the data in respect of mean total dry matter showed that the maximum values were recorded by Phule

bhaskar variety in all the windows of sowing. The July (S₂) sown crop has taken maximum number of days than late sown crops to attain the different growth stages during the crop growth period. This is due to better amount of moisture available and low values of temperature during the crop growth period of July sown crops. The same trend was obtained in case of GDD this indicates that GDD is a function of bright sunshine hours which reflected into a better grain yield..

Table.1 Mean grain yield (kg ha⁻¹) of *Kharif* Sunflower as influenced by various sowing dates and varieties (2013 to 2017)

Treatment	2013	2014	2015	2016	2017	Mean	Sur/def (%)	SYI
Main=3 Sowing dates								
S ₁ = MW 26 (June 26-July 01) 2 nd fortnight of June	1871.3	2109.4	491.1	1467.4	880.4	1363.9	7.3 % high over mean	0.33
S ₂ = MW 30 (July 23-29 July) 2 nd fortnight of July	2154.5	2392.6	827.7	1978.9	1187.3	1708.2	34.4 % high over mean	0.43
S ₃ = MW 35 (August 27-Sept 2) 2 nd fortnight of August	784.2	1022.3	543.7	849.1	509.5	741.7	41.7 % less over mean	0.52
Mean	1603.3	1841.4	620.8	1431.8	859.1	1271.3		0.41
Sub=3 Varieties								
V ₁ = Bhanu	1322.0	1560.1	605.9	1159.9	696.0	1068.8	15.9 % less over mean	0.42
V ₂ = MSFH-17	1590.7	1828.8	576.8	1559.3	935.6	1298.2	2.1 % high over mean	0.42
V ₃ = Phule Bhaskar	1897.3	2135.3	679.7	1576.1	945.7	1446.8	13.8 % high over mean	0.39
Mean	1603.3	1841.4	620.8	1431.8	859.1	1271.3		0.41
Sub-Sub= 2 Treatments								
T1=Protected	1789.0	2027.1	718.3	1600.6	960.3	1419.0	11.6 % high over mean	0.43
T2=Unprotected	1417.7	1655.8	523.3	1263.0	757.8	1123.5	11.6 % less over mean	0.39
Mean	1603.3	1841.4	620.8	1431.8	859.1	1271.3		0.41
S.E.± (Sowing dates)	45.37	45.4	14.8	36.8	22.1	125.5		
C.D. at 5 %	178.16	178.2	58.1	144.5	86.7	409.2		
S.E.± (Varieties)	78.80	78.8	26.4	35.6	21.4	41.5		
C.D. at 5 %	242.80	242.8	81.3	109.6	65.8	121.1		
S.E.± (SD X V)	136.48	136.5	45.7	61.6	37.0	71.8		
C.D. at 5 %	NS	NS	NS	189.9	113.9	NS		
S.E.± (Treatment)	4.51	4.5	18.4	45.6	27.4	18.4		
C.D. at 5 %	13.41	13.4	54.7	135.6	81.3	52.7		
S.E.± (SD x Treatment)	13.54	13.5	31.9	79.0	47.4	31.8		
C.D. at 5 %	40.22	40.2	94.8	NS	NS	91.2		
S.E.± (Treatment X Variety)	13.54	13.5	31.9	79.0	47.4	31.8		
C.D. at 5 %	NS	NS	NS	NS	NS	NS		

Table.2 Mean total monetary returns of *Kharif* Sunflower as influenced by various sowing dates and varieties (2013 to 2017)

Treatment	2013	2014	2015	2016	2017	Mean	SYI
Main=3 Sowing dates							
S ₁ = MW 26 (June 26-July01) 2 nd fortnight of June	58730	55326	21925	55762	33457	45040	0.49
S ₂ = MW 30 (July. 23-29) 2 nd fortnight of July	66444	61624	33216	75197	45118	56320	0.52
S ₃ = MW 35 (August 27-Sept 2) 2 nd fortnight of August	26005	28037	20650	32267	19360	25264	0.62
Mean	50393	48329	25263	54409	32645	42208	0.54
Sub=3 Varieties							
V ₁ = Bhanu	42303	41646	25061	44077	26446	35907	0.60
V ₂ = MSFH-17	49736	47736	23357	59255	35553	43128	0.49
V ₃ = Phule Bhaskar	59140	55606	27372	59894	35936	47590	0.55
Mean	50393	48329	25263	54409	32645	42208	0.54
Sub-Sub= 2 Treatments							
T1=Protected	56132	53140	29039	60822	36493	47125	0.55
T2=Unprotected	44654	43518	21487	47995	28797	37290	0.54
Mean	50393	48329	25263	54409	32645	42208	0.54
S.E.± (Sowing dates)	1360.63	1133.8	559.3	1398.4	839.0	3319.3	
C.D. at 5 %	5342.49	4451.7	2195.9	5490.8	3294.5	10824.7	
S.E.± (Varieties)	2351.68	1957.7	1009.5	1352.2	811.3	1291.5	
C.D. at 5 %	7246.23	6032.4	3110.5	4166.5	2499.9	3769.5	
S.E.± (SD X V)	4073.22	3390.9	1748.5	2342.1	1405.2	2236.9	
C.D. at 5 %	NS	NS	NS	7216.7	4330.0	NS	
S.E.± (Treatment)	134.59	112.0	681.6	1733.7	1040.2	530.1	
C.D. at 5 %	399.87	332.9	2025.2	5151.1	3090.7	1520.3	
S.E.± (SD x Treatment)	403.76	336.1	1180.6	3002.9	1801.7	918.1	
C.D. at 5 %	1199.62	998.6	3507.7	NS	NS	2633.2	
S.E.± (Treatment X Variety)	403.76	336.1	1180.6	3002.9	1801.7	918.1	
C.D. at 5 %	NS	NS	NS	NS	NS	NS	

Table.3 CUM and MUE as influenced by different treatments in *Kharif* sunflower (2013 to 2017)

Treatment	GY (kg ha ⁻¹)	CUM (mm)	MUE (kg ha ⁻¹ mm)	Treatment	GY (kg ha ⁻¹)	CUM (mm)	MUE (kg ha ⁻¹ mm)
S ₁ V ₁ T ₁	1305	268	4.9	S ₂ V ₂ T ₂	1716	317	5.4
S ₁ V ₁ T ₂	1013	242	4.2	S ₂ V ₃ T ₁	1977	337	5.9
S ₁ V ₂ T ₁	1495	308	4.9	S ₂ V ₃ T ₂	1822	316	5.8
S ₁ V ₂ T ₂	1298	298	4.4	S ₃ V ₁ T ₁	782	254	3.1
S ₁ V ₃ T ₁	1700	312	5.4	S ₃ V ₁ T ₂	424	215	2.0
S ₁ V ₃ T ₂	1373	280	4.9	S ₃ V ₂ T ₁	941	281	3.3
S ₂ V ₁ T ₁	1604	326	4.9	S ₃ V ₂ T ₂	494	192	2.6
S ₂ V ₁ T ₂	1285	291	4.4	S ₃ V ₃ T ₁	1123	293	3.8
S ₂ V ₂ T ₁	1846	333	5.5	S ₃ V ₃ T ₂	686	221	3.1

Table.4 Number days required to attain phenological stages as influenced by sowing dates in sunflower (2013 to 2017)

Sowing Time	Phenological stage						
	Emer.	4 leaf	Button	50 % flowering	Soft dough	Hard dough	Phy. Maturity
S ₁ V ₁	8	6	25	11	8	8	7
Cumulative	8	14	39	50	58	66	73
S ₁ V ₂	7	8	26	10	8	7	6
Cumulative	7	15	41	51	59	66	72
S ₁ V ₃	6	7	24	11	7	6	6
Cumulative	6	13	37	48	55	61	67
S ₂ V ₁	7	7	28	12	8	7	7
Cumulative	7	14	42	54	62	69	76
S ₂ V ₂	8	7	30	13	8	10	8
Cumulative	8	15	45	58	66	76	84
S ₂ V ₃	8	8	32	13	11	12	8
Cumulative	8	16	48	61	72	84	92
S ₃ V ₁	7	6	27	11	7	10	7
Cumulative	7	13	40	51	58	68	75
S ₃ V ₂	6	7	29	12	8	8	8
Cumulative	6	13	42	54	62	70	78
S ₃ V ₃	7	10	30	11	9	8	7
Cumulative	7	17	47	58	67	75	82

Table.5 Growing degree days required to attain phenological stages as influenced by sowing dates in sunflower (2013 to 2017)

Sowing Time	Phenological stage						
	Emer.	4 leaf	Button	50 % flowering	Soft dough	Hard dough	Phy. Maturity
S ₁ V ₁	83	75	185	54	68	101	84
Cumulative	83	158	343	397	465	566	650
S ₁ V ₂	86	93	240	124	86	176	90
Cumulative	86	179	419	543	629	805	895
S ₁ V ₃	64	90	72	55	87	193	103
Cumulative	64	154	226	281	368	561	664
S ₂ V ₁	84	82	192	134	185	210	116
Cumulative	84	166	358	492	677	887	1003
S ₂ V ₂	84	101	286	111	106	186	125
Cumulative	84	185	471	582	688	874	999
S ₂ V ₃	83	126	289	145	165	210	107
Cumulative	83	209	498	643	808	1018	1125
S ₃ V ₁	88	107	186	70	85	105	109
Cumulative	88	195	381	451	536	641	750
S ₃ V ₂	72	91	186	88	86	105	84
Cumulative	72	163	349	437	523	628	712
S ₃ V ₃	86	106	230	59	82	102	85
Cumulative	86	192	422	481	563	665	750

Table.6 Periodical dry matter (g m^{-2}) and its partitioning into different parts of sunflower (2013 to 2017)

Sowing Date	Growth Stage					
	4 Leaf	Button	50% flow.	Soft Dough	Hard Dough	Phy. Maturity
S ₁ V ₁	1.8	62.3	111.0	166.4	217.2	285.2
S ₁ V ₂	1.6	73.3	116.2	186.0	229.0	318.9
S ₁ V ₃	1.9	83.8	134.1	211.0	276.5	357.2
S ₂ V ₁	1.9	88.5	149.1	235.7	315.6	369.4
S ₂ V ₂	2.3	93.5	156.3	260.8	334.9	398.6
S ₂ V ₃	2.0	106.7	174.6	295.0	373.3	434.4
S ₃ V ₁	1.6	73.5	142.3	223.9	317.7	356.4
S ₃ V ₂	1.7	91.8	150.3	254.9	337.7	387.5
S ₃ V ₃	2.0	99.8	168.4	279.3	364.5	420.8

Table7 Leaf area index as influenced by sowing dates in sunflower (2013 to 2017)

Sowing Date	Growth Stage					
	4 Leaf	Button	50% flow.	Soft Dough	Hard Dough	Phy. Maturity
S ₁ V ₁	0.019	0.33	1.06	0.48	0.26	0.03
S ₁ V ₂	0.020	0.32	0.90	0.55	0.25	0.06
S ₁ V ₃	0.018	0.43	1.03	0.68	0.43	0.06
S ₂ V ₁	0.020	0.52	1.27	0.55	0.53	0.15
S ₂ V ₂	0.021	0.48	1.23	0.57	0.47	0.11
S ₂ V ₃	0.023	0.59	1.43	0.78	0.61	0.21
S ₃ V ₁	0.019	0.35	0.96	0.43	0.33	0.03
S ₃ V ₂	0.018	0.47	1.10	0.59	0.43	0.11
S ₃ V ₃	0.017	0.44	1.00	0.64	0.44	0.06

Table.8 Radiation use efficiency (g MJ^{-1}) by sowing dates in sunflower (2013 to 2017)

Sowing Date	Growth Stage					
	4 Leaf	Button	50% flow.	Soft Dough	Hard Dough	Phy. Maturity
S ₁ V ₁	0.09	0.46	1.16	0.79	0.84	0.3
S ₁ V ₂	0.09	0.49	1.15	0.81	0.76	0.4
S ₁ V ₃	0.11	0.55	1.55	0.86	0.72	0.46
S ₂ V ₁	0.12	0.53	1.53	1.27	1.25	0.29
S ₂ V ₂	0.12	0.57	1.64	1.32	1.29	0.47
S ₂ V ₃	0.13	0.63	1.71	1.40	1.31	0.52
S ₃ V ₁	0.09	0.42	0.93	0.66	0.63	0.39
S ₃ V ₂	0.09	0.45	0.93	0.69	0.62	0.42
S ₃ V ₃	0.10	0.49	1.46	0.73	0.71	0.46

Table.9 Correlation coefficient between grain yield and different weather parameters during different phenophases of *kharif* sunflower

Phenophase	Tmax (°C)	Tmin (°C)	RH-1 (%)	RH-2 (%)	WS (kmph)	RF (mm)	SS (hrs day ⁻¹)	EVP (mm)
P1	-0.260	0.184	-0.221	0.342	0.694**	-0.071	-0.464	0.331
P2	-0.233	0.207	-0.428	-0.157	0.512*	-0.044	-0.326	0.216
P3	0.626**	0.334	-0.732**	-0.560*	0.400	-0.704**	-0.020	0.428
P4	-0.453	0.508*	0.544*	0.623**	0.336	0.248	-0.519*	0.544*
P5	-0.509*	0.592**	0.710**	0.657**	0.154	0.754**	-0.450	0.576*
P6	0.342	0.377	0.311	0.146	0.042	0.281	0.074	0.763**
P7	0.353	0.268	0.094	0.182	-0.041	-0.040	-0.049	0.246

Table.10 Stepwise multiple regression of different weather parameters with yield of *kharif* sunflower at soft dough stage (2012 to 2017)

Sr. No.	Weather parameter	Regression coefficient	R ²
1	Intercept	-87.801	0.70
2	Minimum Temperature (T _{min})	-3.864	
3	Relative Humidity (RH-1)	2.338	
4	Relative Humidity (RH-2)	-0.185	
5	Rainfall (RF)	-0.077	
6	Epan	0.372	

Table.11 Observed and predicted yield by using linear regression equations

Treatment	Actual Yield	Predicted Yield	Residuals	Standardized residual
Main treatment – Sowing time				
S ₁ = MW 26 (June 26-July 01) 2 nd fortnight of June	1481.8	1473.0	8.8	-0.248
S ₂ = MW 30 (July 23-29) 2 nd fortnight of July	1763.5	1744.8	18.7	1.101
S ₃ = MW 35 (August 27-Sept 2) 2 nd fortnight of August	995.1	990.8	4.3	-0.853
Sub treatment – variety				
V ₁ = Bhanu	1228.1	1298.4	-70.3	-1.007
V ₂ = MSFH-17	1425.6	1335.2	90.4	0.993
V ₃ = Phule Bhaskar	1586.7	1575.0	11.7	0.014
Sub-Sub= 2 Treatments				
T1=Protected	1601.3	1402.9	198.4	0.707
T2=Unprotected	1225.7	1402.9	-177.2	-0.707

$$\sqrt{\text{Yield}} = -87.801 + (-3.864 \times T_{\min}) + (2.338 \times \text{RH-1}) + (-0.185 \times \text{RH-2}) + (-0.077 \times \text{RF}) + (0.372 \times \text{Epan})$$

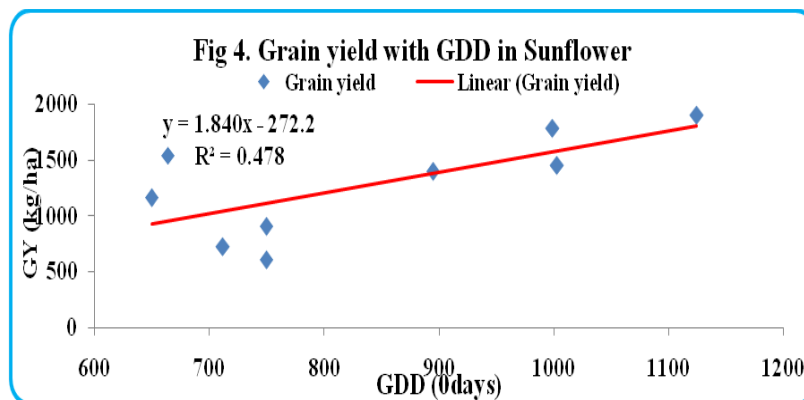
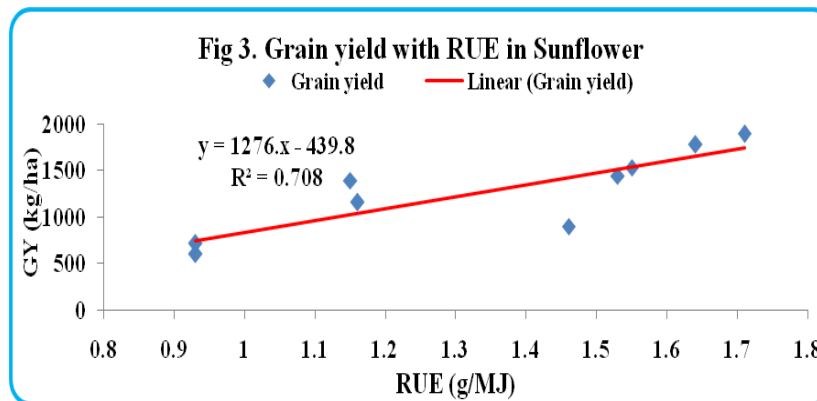
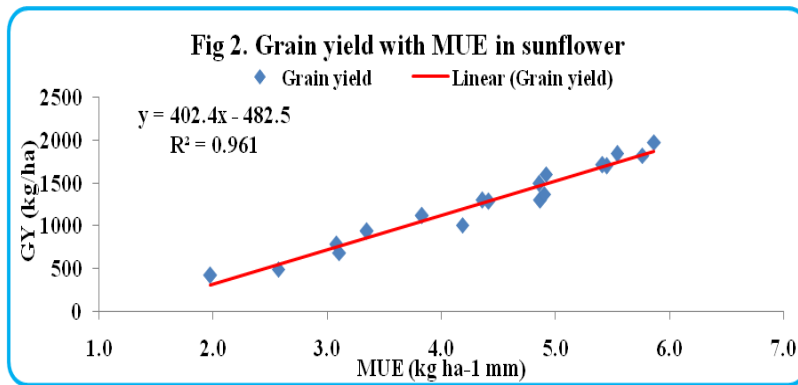
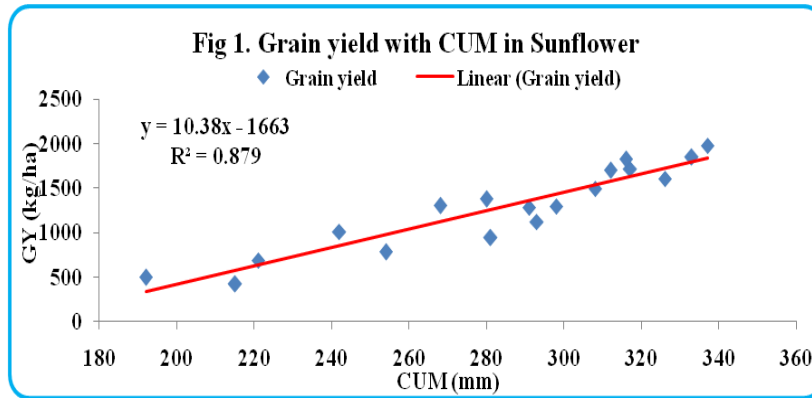
Standard Residual > 3 and < -3 is outlier,

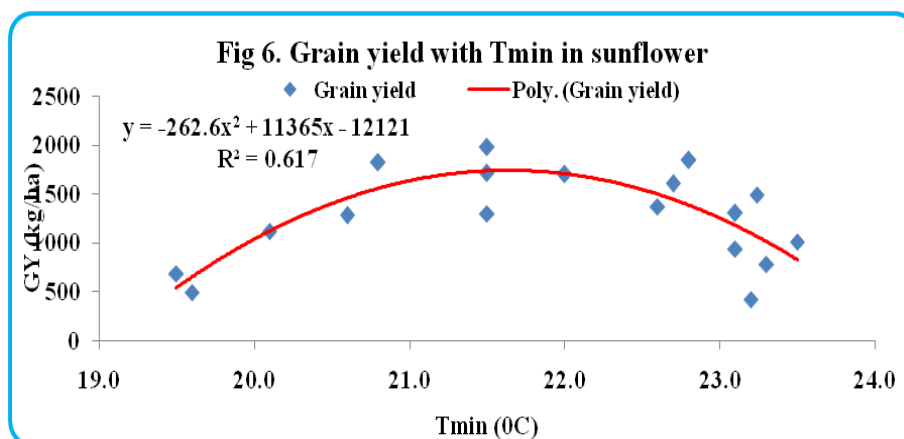
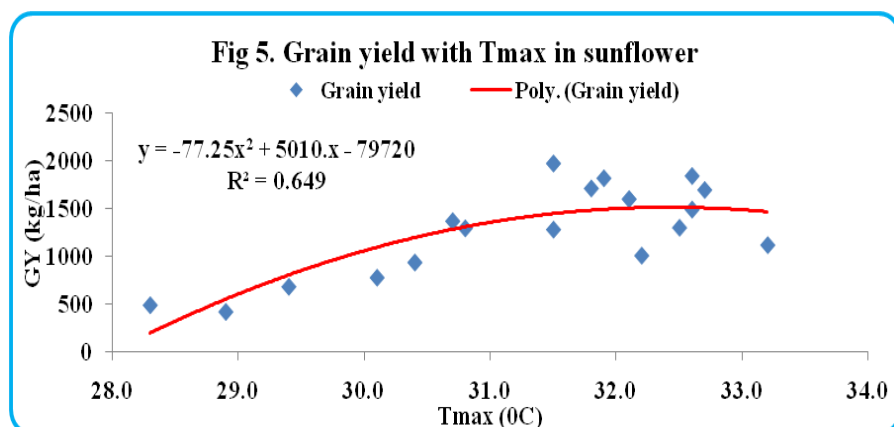
T_{min} = Min. Temperature (°C)

RH-1 = Morning relative humidity (%)

RH-2 = Evening relative humidity (%)

RF = Rainfall (mm)





Correlation regression studies

The weather parameter influence their contribution and performance in *kharif* sunflower crop sown in different sowing windows were assessed in tenure of phase wise correlation and regression (Table 9-11).

The influences of weather parameter and agrometeorological indices on performance of *kharif* sunflower crop sown at different windows with different varieties were assured in terms of phase-wise correlation of grain yield with mentioned weather parameters. It is revealed that the wind speed had significant positive correlation at emergence phase (P₁) and 3 leaf stage (P₂). Tmax had significant positive influence and RH-1, RH-2 and RF has significant negative influence at button phase (P₃). Significant positive correlation was found with Tmin, RH-1, RH-2 and Epan

while BSS has significant negative correlation at 50 % flowering stage (P₄). Tmax had significant negative influence and Tmin, RH-1, RH-2, RF and Epan has significant positive influence at soft dough phase (P₅) while at hard dough stage (P₆) Epan had significant positive association with grain yield.

Significant negative association with grain yield by Tmin, RH-1, RH-2 and RF at button phase (P₃) indicates that at early growth stages *kharif* sunflower not favour moisture stress condition. Significant positive association with grain yield at 50 % flowering stage by Tmin, RH-1, RH-2, RF and Epan indicates *kharif* sunflower responds well to available moisture and low temperature conditions. It is revealed that button phase (P₃) and 50 % flowering stage (P₄) are more crucial growth stages to contribute grain production.

It is observed that the significantly positive correlation (Table 9) of weather parameters namely T_{min} , RH-1, RH-2 and RF with grain yield at soft dough phase. The predicted grain yield and actual pooled grain yield is presented in Table 11. The regression equation is developed by using this weather parameters *i.e.* $\sqrt{Yield} = -87.801 + (-3.864 \times T_{min}) + (2.338 \times RH-1) + (-0.185 \times RH-2) + (-0.077 \times RF) + (0.372 \times E_{pan})$. This equation is helpful to predict grain yield after completion of soft dough phase (P5).

The consumptive use of moisture (CUM) during total growth period of *khariif* Sunflower Fig. 1 showed a linear relationship with grain yield ($y = 10.389x - 1663$ $R^2 = 0.88$). The CUM of 320 mm was found to be optimum for getting higher grain yield. The moisture use efficiency (MUE) during total growth period of *khariif* sunflower Fig. 2 showed a linear relationship with grain yield $y = 402.41x - 482.52$ $R^2 = 0.96$). The MUE of 4.50 to 5.50 kg ha mm⁻¹ was found to be optimum for getting higher grain yield.

The RUE studies depicted in Fig. 3 showed linear relationship with grain yield. This indicated that radiation interception is directly related with grain yield ($y = 1276.9x - 439.81$ $R^2 = 0.71$). The figure showed that if RUE increases from 1.5 to 1.7 g mj⁻¹ it increases the yield from 06 to 10 q ha⁻¹. This indicated that every increase of 0.1 gmj⁻¹ of energy there is increase of 0.9 q ha⁻¹ of grain yield of sunflower.

The GDD was correlated with the grain yield of sunflower and depicted in Fig. 4. It showed a linear relationship with grain yield ($y = 1.8405x - 272.26$ $R^2 = 0.48$). This indicated that with increase of GDD there was increase in grain yield upto 1000 GDD.

The T_{max} was correlated with the grain yield of sunflower and depicted in Fig. 5. It showed

a polynomial relationship with grain yield ($y = -77.257x^2 + 5010.4x - 79720$ $R^2 = 0.65$). This indicated that with increase of T_{max} there was increase in grain yield upto 31.6°C. The T_{min} was correlated with the grain yield of sunflower and depicted in Fig. 6. It showed a polynomial relationship with grain yield ($y = -262.6x^2 + 11365x - 121216$ $R^2 = 0.62$). This indicated that with increase of T_{min} there was increase in grain yield upto 21.6°C

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