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Yield Prediction of Sunflower Using Regression Equation Under Changing Rainfall Situation in Scarcity Zone of Maharashtra

V. T. Jadhav[1*], V. M. Londhe[2], J. D. Jadhav[3] and V. M. Amrutsagar[4]
Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722 (India)
AICRP on Agrometeorology, Zonal Agriculture Research Station, Solapur - 413 002 (India)
*Email : vtj2009@rediffmail.com

Abstract

Present investigation entitled "Yield Prediction of sunflower using regression equation under changing rainfall situation in scarcity zone of Maharashtra." was carried out during 2016-20 at Zonal Agricultural Research Station, Solapur, Mahatma Phule Krishi Vidyapeeth, Rahuri Maharashtra State (India). The experiment was conducted in split plot design with three replications. Nine treatment combinations were formed considering different cultivars *viz*., V_1 Bhanu, V_2 MSFH-17 and V_3 Phule Bhaskar and sowing windows *viz*., (S_1) 2nd fortnight of June (25th - June), (S_2) - 2nd fortnight of July (27th - July), (S_3) - 2nd fortnight of August (24th - August). Among the three sunflower sowing window crop sown in second fortnight of July (S_2) produced significantly highest grain yield (1377.9 kg ha^{-1}) and total monetary returns (52,154/- kg ha^{-1}), CUM (326 mm), MUE (4.33 Kg ha^{-1} mm), GDD (19170 days), RUE July (1.79 g MJ^{-1}) than other dates of sowing. Among the genotypes Phule Bhaskar produced significantly higher grain yield (1200.0 kg ha^{-1}), total monetary returns (Rs. 44675/- ha^{-1}), CUM (314.8 mm), MUE (4.23 Kg ha^{-1} mm), mean number of days to attain physiological stages (92 days), GDD (18150 days).The correlation study revealed that the wind speed had significant positive correlation at emergence phase (P_1) and 3 leaf stage (P_2). Tmax had significant positive influence and RH-I, RH-II and RF has significant negative influence at button phase (P_3).Under changing rainfall situation sowing of *Kharif* sunflower contingent crop in second fortnight of July i.e. 16th July to 29th July (MW 30-31) in medium deep soil of scarcity zone of Maharashtra is recommended. Following regression equation based on weather parameters for predicting the yield (prior to 2 weeks) is recommended. Yield=-86.802-3.860 x Tmin + 2.332 x RH-1-0.182 x RH-2 -0.076 x RF +0.370 x Epan

Key words : *Kharif* sunflower, sowing windows, yield attributes, cultivars.

Oil seed crops play 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 bicolar* 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,

1. Agrometeorologist, 2. Jr.Agronomist, 3. Ex. Agrometeorologist and 4. Chief Scientist.

Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra State (India) during in year 2016-2020 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*., V_1 Bhanu, V_2 MSFH-1 and V_3 Phule Bhaskar and sowing windows *viz*., (S_1) 2nd fortnight of June (25th - June), (S_2) - 2nd fortnight of July (27th -July) S_3 - 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 year^{-1}. The annual maximum and minimum temperature ranged between 25.0 to 43.2°C and 7.3 to 27.1°C, respectively. The gross and net plot sizes were 6.0 x 4.5 m^2 and 4.2 x 3.6 m^2, respectively. All the cultivars were dibbled as per different sowing windows at a spacing of 45 cm x 20 cm.

Results and Discussion

Agronomical studies : The crop sown in second fortnight of July (S_2) produced

Table 1. Mean grain yield (kg ha^{-1}) of *Kharif* Sunflower as influenced by various sowing dates and varieties (2015 to 2020)

Treatment	2015	2016	2017	2018	2020	Mean	Sur/def (%)	SYI
Main=3 Sowing dates								
S_1 = MW 26 (June 26-July 01) 2nd fortnight of June	491.1	1467.4	880.4	1270.4	1153.9	1052.6	1.6% less over mean	0.39
S_2 = MW 30 (July 23-29 July) 2nd fortnight of July	827.7	1978.9	1187.3	1469.9	1426.0	1377.9	28.7% high over mean	0.52
S_3 = MW 35 (August 27-Sept 2) 2nd fortnight of Aug	543.7	849.1	509.5	977.4	1020.4	780.0	27.1% less over mean	0.48
Mean	620.8	1431.8	859.1	1239.2	1200.1	1070.2		0.46
Sub=3 Varieties								
V_1 = Bhanu	605.9	1159.9	696.0	1063.4	1038.0	912.6	14.7% less over mean	0.46
V_2 = MSFH-17	576.8	1559.3	935.6	1201.9	1216.2	1098.0	2.6% high over mean	0.46
V_3 = Phule Bhaskar	679.7	1576.1	945.7	1452.3	1346.0	1200.0	12.1% high over mean	0.47
Mean	620.8	1431.8	859.1	1239.2	1200.1	1070.2		0.46
Sub-Sub= 2 Treatments								
T_1 = Protected	718.3	1600.6	960.3	1422.7	1362.90	1213.1	13.3% high over mean	0.48
T_2 = Unprotected	523.3	1263.0	757.8	1055.7	1037.30	927.4	13.3% less over mean	0.44
Mean	620.8	1431.8	859.1	1239.2	1200.1	1070.2		0.46
S.E.± (Sowing dates)	14.8	36.8	22.1	33.2	43.20	118.9		
C.D. at 5%	58.1	144.5	86.7	130.4	169.6	387.8		
S.E.± (Varieties)	26.4	35.6	21.4	42.3	42.00	37.4		
C.D. at 5%	81.3	109.6	65.8	130.4	129.40	109.1		
S.E.± (SD x V)	45.7	61.6	37.0	73.3	72.7	64.7		
C.D. at 5%	NS	189.9	113.9	225.8	NS	NS		
S.E.± (Treatment)	18.4	45.6	27.4	26.2	25.7	18.0		
C.D. at 5 %	54.7	135.6	81.3	77.8	76.2	51.6		
S.E.± (SD x Treatment)	31.9	79.0	47.4	45.3	44.4	31.2		
C.D. at 5%	94.8	NS	NS	134.7	NS	NS		
S.E.± (Treatment x Variety)	31.9	79.0	47.4	45.3	77.0	31.2		
C.D. at 5%	NS	NS	NS	NS	NS	NS		

significantly highest grain yield (1377.9 kg ha^{-1}) and total monetary returns (52154/- 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 (S_3). It was revealed from that the crop sown at second fortnight of July (S_2) 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 (S_2) 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 (S_1) 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 (1200.0 kg ha^{-1}) and total monetary returns (Rs. 44675/- 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.

Meteorological studies : The mean

Table 2. Mean total monetary returns of Kharif Sunflower as influenced by various sowing dates and varieties (2015 to 2020)

Treatment	2015	2016	2017	2018	2020	Mean	SYI
Main = 3 Sowing dates							
S_1 = MW 26 (June 26-July01) 2nd fortnight of June	21925	47686	33457	48275	37294	40753	0.55
S_2 = MW 30 (July. 23-29) 2nd fortnight of July	33216	58450	45118	55855	45615	52154	0.64
S_3 = MW 35 (August 27-Sept 2) 2nd fortnight of August	20650	23059	19360	37140	26864	25436	0.49
Mean	25263	43065	32645	47090	36591	39447	0.56
Sub=3 Varieties							
V_1 = Bhanu	25061	37076	26446	40410	30200	33486	0.56
V_2 = MSFH-17	23357	43305	35553	45672	35003	40181	0.56
V_3 = Phule Bhaskar	27372	48813	35936	55188	44567	44675	0.57
Mean	25263	43065	32645	47090	36591	39447	0.56
Sub-Sub = 2 Treatments							
T_1 = Protected	29039	48476.3	36493	54062	42920	44483	0.57
T_2 = Unprotected	21487	37653.3	28797	40118	30261	34412	0.55
Mean	25263	43065	32645	47090	36591	39447	0.56
S.E.± (Sowing dates)	559.3	3727.0	839.0	1262.2	1043.3	3038.1	
C.D. at 5%	2195.9	12154.5	3294.5	4955.8	4096.5	9907.9	
S.E.± (Varieties)	1009.5	1272.8	811.3	1607.9	1346.5	1271.1	
C.D. at 5 %	3110.5	3715.2	2499.9	4954.6	4149.0	3710.0	
S.E.± (SD x V)	1748. 5	2204.6	1405.2	2785.0	2332.2	2201.6	
C.D. at 5%	NS	NS	4330.0	8581.6	7186.2	NS	
S.E.± (Treatment)	681.6	772.5	1040.2	994.5	878.0	643.5	
C.D. at 5%	2025.2	2215.5	3090.7	2954.7	2608.8	1845.6	
S.E.± (SD x Treatment)	1180.6	1337.9	1801.7	1722.5	1520.8	1114.6	
C.D. at 5%	3507.7	NS	NS	5117.8	4518.6	NS	
S.E.± (Treatment x Variety)	1180.6	1337.9	1801.7	1722.5	2634.1	1114.6	
C.D. at 5%	NS	NS	NS	NS	NS	NS	

Table 3. CUM and MUE as influenced by different treatments in *Kharif* sunflower (2015 to 2020)

Treatment	GY (kg ha^{-1})	CUM (mm)	MUE (kg ha^{-1} mm)
$S_1V_1T_1$	1208	300.0	4.0
$S_1V_1T_2$	776	280.0	2.8
$S_1V_2T_1$	1228	320.0	3.8
$S_1V_2T_2$	1122	300.0	3.7
$S_1V_3T_1$	1385	329.0	4.2
$S_1V_3T_2$	1204	300.0	4.0
$S_2V_1T_1$	1564	330.0	4.7
$S_2V_1T_2$	959	270.0	3.6
$S_2V_2T_1$	1640	340.0	4.8
$S_2V_2T_2$	1213	320.0	3.8
$S_2V_3T_1$	1729	360.0	4.8
$S_2V_3T_2$	1451	340.0	4.3
$S_3V_1T_1$	1027	250.0	4.1
$S_3V_1T_2$	693	230.0	3.0
$S_3V_2T_1$	1151	280.0	4.1
$S_3V_2T_2$	944	260.0	3.6
$S_3V_3T_1$	1333	300.0	4.4
$S_3V_3T_2$	974	260.0	3.7

consumptive use of moisture CUM (326.6 mm) and mean moisture use efficiency MUE (4.33 Kg ha^{-1} mm) was significantly higher recorded by crop sown in second fortnight of July (S_2) over rest of the sowing windows. 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 (314.8 mm) and MUE (4.23 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 (S_2) (Table 4). This might be due to more favorable conditions prevailed in case early sown crop and

Table 4. Number days required to attain phenological stages as influenced by sowing dates in sunflower (2015 to 2020)

Sowing time	Phenological stage						
	Emer.	4 leaf	Button	50 % flowering	Soft dough	Hard dough	Phy. maturity
S_1V_1	8	6	25	11	8	8	7
Cumulative	8	14	39	50	58	66	73
S_1V_2	7	8	26	10	8	7	6
Cumulative	7	15	41	51	59	66	72
S_1V_3	6	7	24	11	7	6	6
Cumulative	6	13	37	48	55	61	67
S_2V_1	7	7	28	12	8	7	7
Cumulative	7	14	42	54	62	69	76
S_2V_2	8	7	30	13	8	10	8
Cumulative	8	15	45	58	66	76	84
S_2V_3	8	8	32	13	11	12	8
Cumulative	8	16	48	61	72	84	92
S_3V_1	7	6	27	11	7	10	7
Cumulative	7	13	40	51	58	68	75
S_3V_2	6	7	29	12	8	8	8
Cumulative	6	13	42	54	62	70	78
S_3V_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 (2015 to 2020)

Sowing time	Phenological stage						
	Emer.	4 leaf	Button	50 % flowering	Soft dough	Hard dough	Phy. maturity
S_1V_1	174	150	604.48	242	202	206	160
Cumulative	325	475	1080	1323	1525	1731	1892
S_1V_2	174	171	626	220	223	268	214
Cumulative	345	517	1143	1363	1587	1855	2070
S_1V_3	174	150	583	223	203	206	162
Cumulative	325	475	1059	1282	1485	1691	1854
S_2V_1	165	166	591	242	199	203	162
Cumulative	332	499	1090	1332	1532	1735	1898
S_2V_2	145	166	653	258	181	245	239
Cumulative	311	477	1131	1390	1572	1817	2057
S_2V_3	165	145	591	225	155	205	163
Cumulative	311	456	1048	1273	1428	1633	1797
S_3V_1	184	144	625	278	187	179	147
Cumulative	328	472	1097	1376	1563	1742	1890
S_3V_2	163	165	645	258	169	216	214
Cumulative	328	493	1138	1397	1566	1782	1997
S_3V_3	162	144	582	239	194	183	143
Cumulative	307	452	1034	1274	1469	1652	1796

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 (S_2) recorded highest mean value of growing degree days (GDD) (19170 days) than other windows of sowing. It indicates that as a GDD is a function of temperature, during July (S_2) sown crop might be grown under high temperature condition and hence recorded highest values of GDD. Further, it is seen that S_2 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

Table 6. Periodical dry matter (g m^{-2}) and its partitioning into different parts of sunflower (2015 to 2020)

Sowing time	Growth stage					
	4 leaf	Button	50 % flowering	Soft dough	Hard dough	Phy. maturity
S_1V_1	1.8	62.3	111.0	166.4	217.2	285.2
S_1V_2	1.6	73.3	116.2	186.0	229.0	318.9
S_1V_3	1.9	83.8	134.1	211.0	276.5	357.2
S_2V_1	1.9	88.5	149.1	235.7	315.6	369.4
S_2V_2	2.3	93.5	156.3	260.8	334.9	398.6
S_2V_3	2.0	106.7	174.6	295.0	373.3	434.4
S_3V_1	1.6	73.5	142.3	223.9	317.7	356.4
S_3V_2	1.7	91.8	150.3	254.9	337.7	387.5
S_3V_3	2.0	99.8	168.4	279.3	364.5	420.8

Table 7. Radiation use efficiency (g MJ^{-1}) by sowing dates in sunflower (2015 to 2020)

Sowing time	Growth stage					
	4 leaf	Button	50 % flowering	Soft dough	Hard dough	Phy. maturity
S_1V_1	0.11	0.51	1.40	1.22	0.94	0.36
S_1V_2	0.13	0.59	1.55	1.37	1.28	0.47
S_1V_3	0.14	0.63	1.64	1.55	1.40	0.61
S_2V_1	0.12	0.51	1.74	1.54	1.33	0.69
S_2V_2	0.09	0.55	1.80	1.66	1.45	0.89
S_2V_3	0.12	0.61	1.84	1.71	1.51	0.95
S_3V_1	0.08	0.48	1.20	0.91	1.02	0.48
S_3V_2	0.09	0.51	1.20	0.94	1.11	0.51
S_3V_3	0.11	0.55	1.60	0.98	1.23	0.55

stage in soybean crop. However, among the varieties the values of mean GDD were higher in Phule Bhaskar (18150 days) followed by MSFH-17 and Bhanu variety. This is due to more duration required by S_2 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 (S_2) sown crop required more number of days to attain various growth stages. This is due to existence of favorable 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 S_2 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 RUE recorded by the crop sown in second fortnight of July (1.79 g MJ^{-1}) (Table 6) 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

Table 8. Correlation coefficient between grain yield and different weather parameters during different phenophases of kharif sunflower

Phenophase	MAXT (°C)	MINT (°C)	RH1 (%)	RH2 (%)	WS (kmph)	RF (mm day^{-1})	SS (hrs day^{-1})	EVP (mm day^{-1})
P_1	-0.260	0.184	-0.221	0.342	0.694**	-0.071	-0.464	0.331
P_2	-0.233	0.207	-0.428	-0.157	0.512*	-0.044	-0.326	0.216
P_3	0.626**	0.334	-0.732**	-0.560*	0.400	-0.704**	-0.020	0.428
P_4	-0.453	0.508*	0.544*	0.623**	0.336	0.248	-0.519*	0.544*
P_5	-0.509*	0.592**	0.710**	0.657**	0.154	0.754**	-0.450	0.576*
P_6	0.342	0.377	0.311	0.146	0.042	0.281	0.074	0.763**
P_7	0.353	0.268	0.094	0.182	-0.041	-0.040	-0.049	0.246

of RUE (1.69 g MJ^{-1}) than MSFH-17 and Bhanu variety for conversion of light into dry matter in all the dates of sowing (Table 6). The July (S_2) 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.

Correlation Regression Studies : The weather parameter influence their contribution and performance in *Kharif* sunflower crop sown in different sowing windows were assessed.

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 (P_1) and 3 leaf stage (P_2). Tmax had significant positive influence and RH-1, RH-2 and RF has significant negative influence at button phase (P_3). Significant positive correlation was found with Tmin, RH-1, RH-2 and Epan while BSS has significant negative correlation at 50 % flowering stage (P_4). Tmax had significant negative influence and Tmin, RH-I, RH-II, RF and Epan has significant positive influence at soft dough phase (P_5) while at hard dough stage (P_6) Epan had significant positive association with grain yield.

Significant negative association with grain yield by Tmin, RH-I, RH-II and RF at button phase (P_3) 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-I, RH-II, RF and Epan indicates *Kharif* sunflower responds well to available moisture and low temperature conditions. It is revealed that button phase (P_3) 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 Tmin, RH-I, RH-II and RF with grain yield at soft dough phase. The predicted grain yield and actual pooled grain yield is presented in Table 10. The regression equation is developed by using this weather parameters i.e. Yield=-86.802-3.860 x Tmin+2.332 x RH-1-0.182 x RH-2 -0.076 x RF +0.370 x Epan. This equation is helpful to predict grain yield after completion of soft dough phase (P_5).

The consumptive use of moisture (CUM) during total growth period of *kharif* Sunflower Fig. 1 showed a linear relationship with grain yield (y=7.2534 x -963.44 R^2 = 0.8279). The CUM of 326.6 mm was found to be optimum for getting higher grain yield. The moisture use efficiency (MUE) during total growth period of *kharif* sunflower Fig. 2 showed a linear relationship with grain yield y = 477.1 x -698.48 R^2 = 0.8665). The MUE of 4.33 kg ha mm^{-1} was found to be optimum for getting higher grain yield.

The RUE studies depicted in **Fig. 3** showed

Table 9. Stepwise multiple regression of different weather parameters with yield of kharif sunflower at soft dough stage (2012 to 2017)

Weather parameter	Regression coefficient	R^2
Intercept	-87.801	0.70
Minimum Temperature (T_{min})	-3.864	
Relative Humidity (RH-1)	2.338	
Relative Humidity (RH-2)	-0.185	
Rainfall (RF)	-0.077	
Epan	0.372	

Table 10. Observed and predicted yield by using linear regression equations.
√Yield=-86.802 - 3.860 x Tmin + 2.332 x RH-1 - 0.182 x RH-2 - 0.076 x RF + 0.370 x Epan

Treatment	Actual yield	Predicted yield	Residuals	Standardized residual
Main treatment - Sowing time				
S_1 = MW 26 (June 26-July 01) 2nd fortnight of June	1481.8	1473.0	8.8	-0.248
S_2 = MW 30 (July 23-29) 2nd fortnight of July	1763.5	1744.8	18.7	1.101
S_3 = MW 35 (August 27-Sept 2) 2nd 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				
T_1 = Protected	1601.3	1402.9	198.4	0.707
T_2 = Unprotected	1225.7	1402.9	-177.2	-0.707

Standard Residual > 3 and < -3 is outleter, T_{min} = Min. Temperature (°C), RH-I = Morning relative humidity (%), RH-II = Evening relative humidity (%), RF = Rainfall (mm)

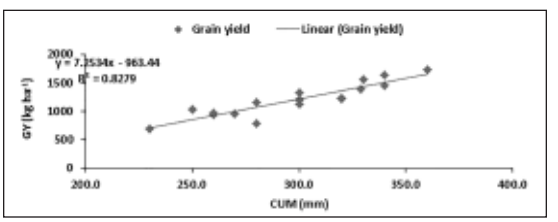

Fig. 1. Grain yield with CUM in Sunflower

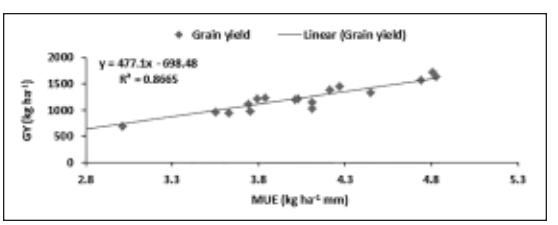

Fig. 2. Grain yield with MUE in sunflower

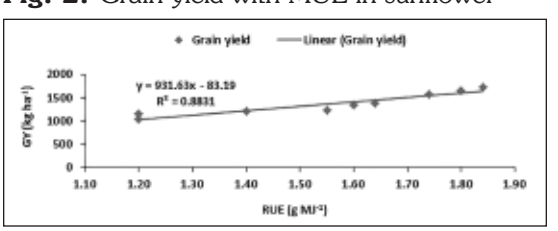

Fig. 3. Grain yield with RUE in Sunflower

linear relationship with grain yield. This indicated that radiation interception is directly related with grain yield (y = 931.63 x –83.19 R^2 = 0.8831). The figure showed that if RUE increases from 1.7 to 1.8 g mJ^{-1} it increases the yield .

The GDD was correlated with the grain yield of sunflower and depicted in Fig. 4. It showed a linear relationship with grain yield (y= 2.2611 x -2971.9 R^2 = 0.9521). This indicated that with increase of GDD there was increase in grain yield.

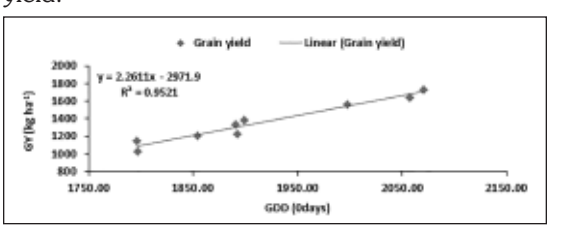

Fig. 4. Grain yield with GDD in Sunflower

The Tmax was correlated with the grain yield of sunflower and depicted in Fig. 5. It showed a polynomial relationship with grain yield (y = -4347.3 x 2 -284109 x + 5E + 06 R^2 = 0.7854). This indicated that with increase of T_{max} there was increase in grain yield up to 32.3°C. The T_{min} was correlated with the grain yield of sunflower and depicted in Fig. 6 It

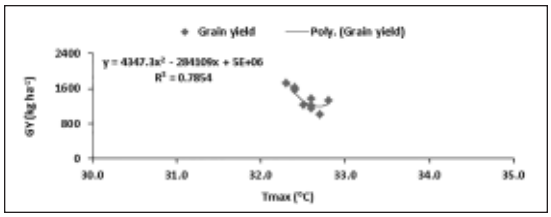

Fig. 5. Grain yield with T_{max} in sunflower

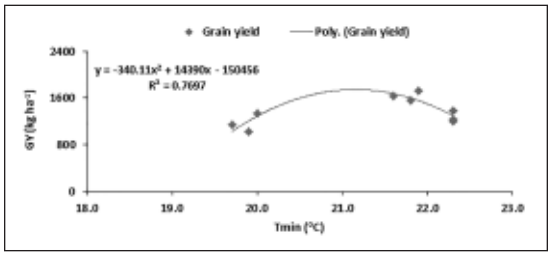

Fig. 6. Grain yield with T_{min} in sunflower

showed a polynomial relationship with grain yield (y=-340.11 x^2 + 14390 x-150456 R^2 = 0.7697). This indicated that with increase of Tmin there was increase in grain yield upto 21.3°C.

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