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CROP GROWTH PREDICTION IN SUNFLOWER USING WEATHER VARIABLES IN A RAINFED ALFISOL

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SUMMARY

Based on the data of weather variables and plant traits collected from field experiments with 7 genotypes of sunflower conducted in 6 *kharif* seasons during 1994 to 1999 in a rainfed alfisol, an attempt has been made in this paper to predict plant growth and identify weather variables which significantly influence the plant growth as measured by different plant traits. Regression diagnostics like predictability (R^2) and prediction error (σ) have been derived to assess the influences of rainfall, sunshine hours, maximum and minimum temperature, relative humidity and vapor pressure deficit at 7 AM and 2 PM on leaf nitrogen, leaf area, leaf weight, leaf number, stomatal conductance, photosynthesis, stem weight and stem nitrogen 30, 45 and 60 days after sowing. Positive and significant influence of (i) sunshine hours, minimum temperature, relative humidity and vapor pressure deficit at 7 AM on stomatal conductance, (ii) vapor pressure deficit at 2 PM on photosynthesis, and negative and significant influence of (i) relative humidity and vapor pressure deficit at 7 AM and 2 PM on leaf N, (ii) minimum temperature and vapor pressure deficit at 7 AM on leaf number, and (iii) minimum temperature, relative humidity and vapor pressure deficit at 7 AM on stem N were observed. Based on a graphical plot of 64 combinations of predictability (R^2) and error in prediction (σ) of plant traits through weather variables, the influences have been categorized into 4 groups viz., high R^2 and low σ (Group I), high R^2 and high σ (Group II), low R^2 and high σ (Group III) and low R^2 and low σ (Group IV). Based on the regression diagnostics of 64 pairs of weather and plant variables, 30 were in Group III, 27 in Group I, 5 in Group II and 2 in Group IV. All plant traits were significantly predictable with minimal error through relative humidity at 7 AM (except leaf area) followed by sunshine hours (except leaf N and photosynthesis), relative humidity and vapor pressure deficit at 2 PM (except leaf number, stem N and stomatal conductance) in Group I. Significant influence of rainfall on leaf and stem weight and vapor pressure deficit at 7 AM on stem N and stomatal conductance were also observed in the study. The influences of weather variables on the remaining plant traits were found to be either non-significant or they occurred with a higher prediction error in the 6 years of study.

Key words: **estimates of correlation, regression analysis, plant traits, weather variables, predictability, error in prediction**

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INTRODUCTION

The physiological growth of a plant could be measured with different plant traits which are correlated in nature. Apart from many controllable factors, the growth of a plant depends on many uncontrollable factors of environment under which it has to grow. The environmental factors influence the growth of a plant more significantly under rainfed conditions than under irrigated conditions. The physiological growth of a plant is a function of different weather variables like rainfall, minimum and maximum temperature, sunshine hours, relative humidity and vapor pressure deficit. Plant growth changes whenever there is a change in the different weather variables and it could be measured and tested based on the procedures discussed by Draper and Smith (1973), Rao (1973) and Maruthi Sankar (1986). An ideal physiological growth of a plant is possible only when the effects of weather parameters are consistent and as per the desired optimal requirements of the plant. In many situations, the growth of a plant is inconsistent due to the random nature of highly erratic weather variables. Plant traits depend to a large extent on the occurrence of biotic and abiotic stresses. There is a need to identify dominant plant traits which are consistent and which contribute significantly to plant growth at different stages and to the resultant seed yield at harvest. Crop productivity is affected by poor physiological growth at different growth stages as influenced by random weather variables. Maruthi Sankar *et al.* (1999) assessed the variability of 8 plant traits for sunflower growth and reduced the dimensionality to two principal components which accounted for about 80% of variance in the original data of plant traits. One of the main objectives in rainfed agriculture is to quantify the effects of weather variables on plant traits, apart from identifying the plant traits which would ideally respond to non-uniform changes of environmental factors. If the effects are efficiently derived, it is possible to correctly interpret the plant growth mechanism under aberrant weather conditions, apart from providing scope for plant breeders to breed new varieties which are drought resistant. Maruthi Sankar *et al.* (2001) discussed a regression procedure for selecting superior sunflower genotypes after identifying plant traits which are dominant on different days after sowing. An attempt is made in this paper to derive the influence of weather variables on different plant traits at vegetative, flowering and reproductive stages of sunflower with the data of 6 field experiments conducted under rainfed conditions in a dryland alfisol.

MATERIALS AND METHODS

With the twin objectives of assessing the effects of weather variables on plant traits and identifying plant traits which are consistent in growth over a period, 6 field experiments of sunflower (*Helianthus annuus* L.) with 5 hybrids viz., MSFH-8, MSFH-17, KBSH-1, JWALA and PAC-36 and two varieties GUJ-SUN-1 and MORDEN were conducted in *kharifs* 1994 to 1999 (June to October) in a rainfed alfisol at Hayathnagar research farm administered by Central Research Institute for Dryland Agriculture, Hyderabad. The dates of sowing and harvest along with the rainfall received up to 30, 45 and 60 days after sowing (DAS) during crop growth in each season are given below:

Season	Date of sowing	Date of harvest	Rainfall (mm)		
			30 DAS	45 DAS	60 DAS
1994	6th July	19th October	72.2	107.0	69.2
1995	3rd July	25th October	18.3	18.6	124.0
1996	8th July	10th October	142.0	86.0	226.0
1997	4th July	14th October	88.1	6.7	69.2
1998	9th July	20th October	194.2	193.5	55.5
1999	5th July	21st October	185.5	22.6	21.3

The experiments were conducted in 4 m x 3 m plots with 3 replicates in a randomized block design. Observations on 8 plant traits viz., leaf area (cm^2), leaf weight (g/plant), leaf nitrogen (%), leaf number, stem weight (g/plant), stem nitrogen (%), stomatal conductance (cm/sec) and photosynthesis ($\mu mol/m^2/sec$) were collected 30, 45 and 60 days after sowing for assessing plant growth. The means and coefficients of variation (%) of the different plant traits as measured 30, 45 and 60 days after sowing over 6 seasons are given in Table 1.

Table 1: Mean and coefficient of variation of plant traits in sunflower on different days after sowing in 6 *kharif* seasons

Variables	30 DAS		45 DAS		60 DAS	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Plant traits						
LN	2.97	58.7	3.16	47.7	2.34	51.9
LA	464.49	38.8	1531.23	32.6	2023.23	35.2
LW	2.03	50.0	7.14	46.8	11.20	38.1
NU	13.68	16.6	21.23	6.70	24.68	12.8
SN	0.98	51.7	1.54	38.3	0.82	54.5
SW	1.18	53.7	6.11	52.1	14.04	46.6
SC	2.11	0.30	1.26	56.9	2.03	27.0
PS	23.48	27.4	26.31	14.0	23.95	18.8
Weather variables						
RF	117	59.3	72	99.1	94	77.0
SS	5	31.8	5	23.7	4	41.9
MAXT	32	3.6	31	13.9	32	1.6
MINT	23	10.0	22	8.8	23	102.
RH1	86	5.4	82	5.1	87	6.3
RH2	64	8.2	63	10.6	70	10.4
VPD1	20	3.1	19	3.1	19	4.1
VPD2	20	4.2	19	5.8	20	6.9

LA: Leaf area (cm^2) LW: Leaf weight (g) LN: Leaf nitrogen (%)
NU: Leaf number SW: Stem weight (g) SN: Stem nitrogen (%)
PS: Photosynthesis ($\mu mol\ m^{-2} sec^{-1}$) SC: Stomatal Conductance ($cm\ sec^{-1}$)
MAXT: Maximum temperature MINT: Minumum temperature
RH1: Relative humidity (7AM) RH2: Relative humidity (2PM)
VPD1: Vapor pressure deficit (7AM) VPD2: Vapor pressure deficit (2PM)
RF: Rainfall SS: Sunshine hours
DAS: Days after sowing CV: Coefficient of variation (%)

Leaf number had the lowest variation of 16.6, 6.7 and 12.8%, while leaf N, stomatal conductance and stem N had highest variation of 58.7, 56.9 and 54.5% on 30, 45 and 60 days after sowing, respectively. Leaf N, stem N and photosynthesis were higher on the 45th day after sowing with a lower coefficient of variation when compared with 30 and 60 days after sowing. Leaf area, leaf weight, leaf number and stem weight were found to be higher on the 60th day after sowing with a lower coefficient of variation when compared with 30 and 45 days after sowing. Stomatal conductance was found to be higher on the 30th day after sowing with a lower coefficient of variation when compared with 45 and 60 days after sowing.

Daily observations on different weather variables viz., rainfall (mm), sunshine hours, minimum and maximum temperature (°C), relative humidity (%) at 7 AM and 2 PM, vapor pressure deficit at 7 AM and 2 PM were collected in each of the 6 seasons and used for relating with plant data. The mean and coefficient of variation (%) of different weather variables 30, 45 and 60 days after sowing over 6 seasons are given in Table 1. Rainfall had highest coefficient of variation of 59.3, 99.1 and 77.0% at 30, 45 and 60 days after sowing respectively, while vapor pressure deficit at 7 AM after 30 and 45 days had lowest coefficient of variation of 3.1%, and maximum temperature had lowest variation too (1.6%) on the 60th day after sowing. Rainfall, sunshine hours, maximum and minimum temperature, vapor pressure deficit at 7 AM and 2 PM were maximum with a lower coefficient of variation on 30th day when compared to 45 and 60 days after sowing. Relative humidity at 7 AM and 2 PM was maximum with a higher coefficient of variation on the 60th day when compared with 30 and 45 days after sowing.

Estimates of correlation determined between plant traits and weather variables measured 30, 45 and 60 days after sowing for each genotype over 6 seasons and are given in Table 2. The relations of sunshine hours with stomatal conductance (MSFH-8 and PAC-36), minimum temperature with stomatal conductance (Jwala and Pac-36), stem N (MSFH-8, MSFH-17, KBSH-1 and Jwala) and leaf number (Morden), relative humidity at 7 AM with leaf N (Guj-Sun-1), stomatal conductance (Pac-36) and stem N (MSFH-17, KBSH-1, Jwala and Pac-36), relative humidity at 2 PM with leaf N (MSFH-8, KBSH-1, Jwala and Pac-36), vapor pressure deficit at 7 AM with leaf N (MSFH-17 and Morden), stomatal conductance (Jwala and Pac-36), stem N (MSFH-8, MSFH-17, KBSH-1, Jwala and Pac-36) and leaf number (MSFH-8, MSFH-17 and Morden), vapor pressure deficit at 2 PM and leaf N (MSFH-8 and Pac-36) and photosynthesis (MSFH-8, MSFH-17 and Jwala) were found to be significant. Maximum number of significantly correlated pairs of variables (10 positive and 4 negative) existed for Pac-36, followed by Jwala (9 positive and 4 negative), MSFH-8 and MSFH-17 (8 positive and 5 negative), KBSH-1 (6 positive and 4 negative), Morden (6 positive and 3 negative) and Guj-Sun-1 (6 positive and 1 negative). The estimates of correlation have provided an insight for assessing the influence of weather variables on plant growth as measured by different plant traits in sunflower during 6 seasons.

Table 2: Estimates of correlation between plant traits and weather variables in sunflower in 6 *kharif* seasons

Weather	Plant	Guj-Sun-1	MSFH-8	MSFH-17	KBSH-1	Jwala	Pac-36	Morden
RF	LN	-0.052	0.022	0.021	0.158	-0.001	-0.028	-0.137
RF	PS	0.167	-0.041	0.214	0.124	-0.004	0.290	0.235
RF	LA	-0.293	-0.102	-0.203	-0.246	-0.159	-0.199	-0.153
RF	LW	-0.138	-0.048	-0.140	-0.231	-0.102	-0.206	-0.144
RF	SW	-0.040	-0.037	-0.114	-0.137	-0.014	-0.165	-0.156
RF	SC	-0.006	-0.082	0.092	-0.072	0.128	0.346	-0.097
RF	SN	-0.126	-0.054	-0.301	-0.372	-0.230	-0.558	0.130
RF	NU	-0.282	-0.191	-0.163	-0.050	-0.144	-0.265	-0.081
SS	LN	-0.286	0.229	-0.118	0.053	-0.142	-0.043	-0.105
SS	PS	-0.143	-0.504	0.072	0.414	-0.379	-0.020	-0.257
SS	LA	-0.003	-0.130	-0.095	-0.184	-0.088	0.081	-0.201
SS	LW	-0.069	-0.085	-0.425	-0.074	-0.042	-0.060	-0.062
SS	SW	-0.119	-0.190	-0.134	-0.124	-0.172	-0.105	-0.152
SS	SC	0.538	0.623*	0.366	0.452	0.329	0.610*	0.040
SS	SN	0.354	-0.281	-0.520	-0.499	-0.454	-0.494	-0.505
SS	NU	-0.009	-0.009	0.066	0.161	-0.004	-0.001	0.071
MAXT	LN	0.114	-0.116	-0.026	-0.033	0.091	0.114	-0.059
MAXT	PS	-0.182	-0.176	-0.169	-0.475	-0.208	0.123	-0.231
MAXT	LA	-0.487	-0.221	-0.258	-0.286	-0.269	-0.264	-0.348
MAXT	LW	-0.167	-0.107	-0.182	-0.224	-0.192	-0.120	-0.204
MAXT	SW	-0.150	-0.139	-0.198	-0.215	-0.087	-0.074	-0.206
MAXT	SC	-0.115	-0.175	0.120	-0.329	0.111	-0.209	-0.264
MAXT	SN	-0.316	0.252	0.187	0.131	0.193	-0.071	0.491
MAXT	NU	-0.106	0.003	-0.002	0.014	0.029	-0.094	0.066
MINT	LN	-0.349	-0.341	-0.474	-0.335	-0.369	-0.313	-0.382
MINT	PS	-0.499	-0.315	-0.244	-0.371	-0.213	-0.310	-0.636
MINT	LA	-0.480	-0.219	-0.238	-0.276	-0.296	-0.048	-0.443
MINT	LW	-0.164	-0.048	-0.112	-0.092	-0.114	-0.051	-0.219
MINT	SW	-0.001	0.004	-0.058	-0.033	0.043	0.118	-0.110
MINT	SC	0.544	0.335	0.679*	0.269	0.686*	0.714**	0.194
MINT	SN	-0.213	-0.764**	-0.609*	-0.703*	-0.609*	-0.406	-0.438
MINT	NU	-0.150	-0.370	-0.534	-0.474	-0.321	-0.178	-0.591*
RH1	LN	-0.587*	-0.304	-0.513	-0.392	-0.509	-0.420	-0.495
RH1	PS	0.044	-0.138	0.409	0.537	0.023	0.163	-0.040
RH1	LA	-0.124	0.047	0.050	-0.066	0.038	0.079	-0.245
RH1	LW	-0.018	0.064	0.047	-0.062	0.030	-0.077	-0.072
RH1	SW	0.132	0.181	0.094	0.105	0.164	0.033	-0.047
RH1	SC	0.437	0.439	0.269	0.417	0.284	0.878**	0.061
RH1	SN	0.142	-0.517	-0.725**	-0.766**	-0.667*	-0.717**	-0.538
RH1	NU	0.015	-0.033	-0.026	0.096	0.002	0.017	-0.025

(continued)

Table 2: Estimates of correlation between plant traits and weather variables in sunflower in 6 *kharif* seasons

RH2	LN	-0.455	-0.723**	-0.457	-0.676*	-0.587*	-0.634*	-0.491
RH2	PS	0.248	0.465	0.180	0.086	0.470	0.045	0.214
RH2	LA	0.122	0.297	0.236	0.282	0.238	0.218	0.147
RH2	LW	0.162	0.243	0.162	0.180	0.189	0.073	0.161
RH2	SW	0.376	0.408	0.313	0.340	0.381	0.213	0.265
RH2	SC	-0.153	-0.263	-0.129	-0.111	-0.074	0.243	-0.068
RH2	SN	-0.547	-0.444	-0.120	-0.222	-0.226	0.007	-0.042
RH2	NU	0.439	0.264	0.055	0.003	0.301	0.411	-0.170
VPD1	LN	-0.564	-0.395	-0.669*	-0.361	-0.500	-0.413	-0.576*
VPD1	PS	-0.277	-0.167	-0.086	0.076	0.004	0.021	-0.338
VPD1	LA	-0.473	-0.213	-0.229	-0.348	-0.267	-0.143	-0.491
VPD1	LW	-0.283	-0.149	-0.208	-0.288	-0.217	-0.305	-0.323
VPD1	SW	-0.097	-0.087	-0.163	-0.162	-0.066	-0.171	-0.272
VPD1	SC	0.420	0.241	0.549	0.285	0.579*	0.823**	0.219
VPD1	SN	-0.027	-0.673*	-0.741**	-0.825**	-0.669*	-0.665*	-0.436
VPD1	NU	-0.449	-0.582*	-0.657*	-0.525	-0.528	-0.461	-0.658*
VPD2	LN	-0.466	-0.664*	-0.507	-0.554	-0.562	-0.621*	-0.491
VPD2	PS	0.221	0.577*	0.601*	0.112	0.595*	0.072	0.261
VPD2	LA	-0.001	0.169	0.117	0.104	0.101	0.135	0.017
VPD2	LW	0.055	0.130	0.073	0.047	0.086	-0.073	0.045
VPD2	SW	0.261	0.252	0.210	0.204	0.241	0.050	0.113
VPD2	SC	-0.223	-0.349	-0.046	-0.122	0.004	0.150	0.043
VPD2	SN	-0.413	-0.443	-0.108	-0.188	-0.177	0.086	-0.065
VPD2	NU	0.059	-0.139	-0.334	-0.374	-0.110	0.027	-0.404

* and ** indicate significance at 5% and 1% level, respectively

Table 3: Regression diagnostics of influence of weather variables on plant traits of sunflower in 6 *kharif* seasons

Weather variable	Plant variable	α	β	R^2	s
MAXT	LA	8900.43	-243.15	0.23	806.69
MAXT	LN	4.38	-0.05	0.21	0.66
MAXT	LW	28.22	-0.60	0.14	5.41
MAXT	NU	59.72	-1.25	0.23	6.29
MAXT	PS	36.18	-0.48	0.16	3.30
MAXT	SC	1.92	0.00	0.27	0.58
MAXT	SN	2.19	-0.02	0.30	1.11
MAXT	SW	9.43	-0.18	0.15	4.42
MINT	LA	9539.76	-381.31	0.19	807.72
MINT	LN	8.94	-0.24	0.24	0.66
MINT	LW	22.75	-0.62	0.08	5.55
MINT	NU	71.60	-2.16	0.13	6.73
MINT	PS	61.14	-1.76	0.24	3.17
MINT	SC	-6.45	0.34*	0.33*	0.56
MINT	SN	9.56	-0.34*	0.37*	1.09
MINT	SW	-6.54	0.41	0.14	4.52
RF	LA	1531.53	-2.48	0.22	819.71
RF	LN	2.56	0.00	0.19	0.69
RF	LW	9.28	-0.02	0.32	4.73
RF	NU	22.24	-0.03	0.31	5.83
RF	PS	25.42	0.01	0.22	3.46
RF	SC	1.81	-0.01	0.12	0.64
RF	SN	1.04	0.00	0.21	1.17
RF	SW	7.02	-0.01*	0.40*	3.56
RH1	LA	-90.35	15.38*	0.35*	759.59
RH1	LN	14.24	-0.13*	0.34*	0.56
RH1	LW	-6.96	0.19*	0.33*	4.81
RH1	NU	0.02	-0.15*	0.67*	4.06
RH1	PS	22.43	-0.01	0.31	3.13
RH1	SC	-8.37	0.13*	0.42*	0.45
RH1	SN	4.79	-0.04*	0.42*	0.96
RH1	SW	-8.30	0.23	0.30	3.99
RH2	LA	-782.62	52.11*	0.39*	674.10
RH2	LN	9.37	-0.10*	0.43*	0.51
RH2	LW	2.03	0.08	0.28	4.89
RH2	NU	31.73	-0.18	0.22	6.42
RH2	PS	12.70	0.11*	0.46*	2.81
RH2	SC	0.91	0.01	0.25	0.60
RH2	SN	7.00	-0.09	0.26	1.11

(continued)

Table 3: Regression diagnostics of influence of weather variables on plant traits of sunflower in 6 *kharif* seasons

RH2	SW	-10.15	0.23	0.32	3.94
SS	LA	2492.18	-305.17*	0.43*	670.19
SS	LN	2.71	-0.09	0.12	0.59
SS	LW	7.03	-0.52*	0.40*	4.56
SS	NU	5.85	1.18*	0.59*	4.20
SS	PS	32.52	-1.11	0.21	3.74
SS	SC	0.09	0.39*	0.34*	0.51
SS	SN	1.26	0.04	0.31	0.99
SS	SW	4.52	-0.67*	0.36*	3.53
VPD1	LA	6817.62	-290.00	0.23	805.94
VPD1	LN	17.36	-0.76	0.29	0.63
VPD1	LW	48.64	-2.14	0.15	5.38
VPD1	NU	127.17	-5.68*	0.42*	5.55
VPD1	PS	37.86	-0.90	0.14	3.36
VPD1	SC	-6.68	0.46*	0.36*	0.49
VPD1	SN	6.36	-0.27*	0.48*	0.95
VPD1	SW	30.41	-1.34	0.06	4.66
VPD2	LA	-6605.53	394.56*	0.42*	692.78
VPD2	LN	16.23	-0.67*	0.36*	0.56
VPD2	LW	-10.98	0.91*	0.40*	4.52
VPD2	NU	74.56	-2.74	0.36*	5.66
VPD2	PS	-7.43	1.43*	0.43*	2.86
VPD2	SC	2.83	-0.05	0.14	0.64
VPD2	SN	11.18	-0.50	0.12	1.20
VPD2	SW	-23.04	1.44*	0.41*	3.67

α : Intercept β : Slope σ : Error in prediction
R^2 : Predictability * indicates significance at 5% level

RESULTS AND DISCUSSION

Using the data of plant traits and weather variables recorded 30, 45 and 60 days after sowing in 6 seasons, prediction models of plant traits using weather variables have been calibrated and the regression diagnostics like intercept, slope, predictability (R^2) and error in prediction of a plant trait are given in Table 3. The predictability (R^2) of stomatal conductance and stem N through minimum temperature, stem weight through rainfall, leaf area, leaf N, leaf weight, leaf number, stomatal conductance and stem N through relative humidity at 7 AM, leaf area, leaf N and photosynthesis through relative humidity at 2 PM, leaf area, leaf weight, leaf number, stomatal conductance and stem weight through sunshine hours, leaf number, stomatal conductance and stem N through vapor pressure deficit at 7 AM, and leaf area, leaf N, leaf weight, leaf number, photosynthesis and stem weight through vapor pressure deficit at 2 PM were found to be significant in different seasons. The predictability of stem weight through vapor pressure deficit at 7 AM was lowest (0.06), while leaf number through relative humidity at 7 AM was highest (0.67) in the study. The lowest error in prediction was found for predicting leaf area (σ=670.19) and stem weight (σ=3.53) through sunshine hours, leaf number (σ=0.51) and stomatal conductance (σ=0.45) through relative humidity at 7 AM, leaf N (σ=0.51) and photosynthesis (σ=2.81) through relative humidity at 2 PM, stem N (σ=0.95) through vapor pressure deficit at 7 AM and leaf weight (σ=4.52) through vapor pressure deficit at 2 PM.

The influences of minimum temperature on stomatal conductance, relative humidity at 7 AM on leaf area, leaf weight and stomatal conductance, relative humidity at 2 PM on leaf area and photosynthesis, sunshine hours on leaf number and stomatal conductance, vapor pressure deficit at 7 AM on stomatal conductance, and vapor pressure deficit at 2 PM on leaf area, leaf weight, photosynthesis and stem weight were found to be positive and significant as indicated by the 'β' values in Table 3. Similarly, the influences of minimum temperature on stem N, rainfall on stem weight, relative humidity at 7 AM on leaf N, leaf number and stem N, relative humidity at 2 PM on leaf N, sunshine hours on leaf area, leaf weight and stem weight, vapor pressure deficit at 7 AM on leaf number and stem N, and vapor pressure deficit at 2 PM on leaf N were found to be negative and significant as indicated by the 'β' values in Table 3.

Based on a graphical plot of predictability (R^2) against the errors in prediction (σ) of plant traits through weather variables, the effects of weather variables on plant traits have been categorized into the following 4 groups :

Group I: high predictability and low prediction error

Group II: high predictability and high prediction error

Group III: low predictability and high prediction error

Group IV: low predictability and low prediction error

The grouping of weather variables based on their influences on plant traits as measured based on the regression diagnostics for leaf area, leaf N, leaf weight and leaf number are given in Figure1 and stem N, stem weight, stomatal conductance and photosynthesis are given in Figure 2 It is obvious from the graphical plots that the weather variables have either significantly influenced the plant traits with a high predictability and low error in prediction (Group I) or have provided a low predictability with a high error in prediction (Group III). The limits of predictability and error in prediction of a plant trait along with the weather variables influencing the plant trait in each group are given in Table 4.

Table 4: Grouping of the effects of weather variables on plant traits in sunflower

Plant traits	High predictability and low prediction error		High predictability and high prediction error		Low predictability and high prediction error		Low predictability and low prediction error	
	R^2 and σ	Weather variables	R^2 and σ	Weather variables	R^2 and σ	Weather variables	R^2 and σ	Weather variables
LA	0.3-0.5 (650-750)	RH2 VPD2 SS	0.3-0.5 (750-850)	RH1	-0.3 (750-850)	MINT RF MAXT VPD1	-0.3 (650-750)	
LN	0.3-0.5 (0.5-0.6)	RH1 VPD2 RH2	0.3-0.5 (0.6-0.7)		-0.3 (0.6-0.7)	RF MAXT MINT VPD1	-0.3 (0.5-0.6)	SS
LW	0.25-0.45 (4.4-5.0)	RH2 RF RH1 SS VPD2	0.25-0.45 (5.0-5.6)		0.05-0.25 (5.0-5.6)	MINT MAXT VPD1	0.05-0.25 (4.4-5.0)	
NU	0.4-0.8 (3.5-5.5)	SS RH1	0.4-0.8 (5.5-7.5)	VPD1	-0.4 (5.5-7.5)	MINT RH2 MAXT RF VPD2	-0.4 (3.5-5.5)	
SN	0.3-0.5 (0.85-1.05)	SS RH1 VPD1	0.3-0.5 (1.05-1.25)	MAXT MINT	0.1-0.3 (1.05-1.25)	VPD2 RF RH2	0.1-0.3 (0.85-1.05)	
SW	0.25-0.45 (3.2-4.0)	RH1 RH2 SS RF VPD2	0.25-0.45 (4.0-4.8)		0.05-0.25 (4.0-4.8)	VPD1 MINT MAXT	0.05-0.25 (3.2-4.0)	
SC	0.3-0.5 (0.35-0.55)	SS VPD1 RH1	0.3-0.5 (0.55-0.75)	MINT	0.1-0.3 (0.55-0.75)	RF VPD2 RH2 MAXT	0.1-0.3 (0.35-0.55)	
PS	0.3-0.5 (2.6-3.2)	VPD2 RH2 RH1	0.3-0.5 (3.2-3.8)		0.1-0.3 (3.2-3.8)	VPD1 MAXT SS RF	0.1-0.3 (2.6-3.2)	MINT

Values in parentheses indicate errors in prediction

Based on the regression diagnostics of 64 pairs of weather and plant variables, 30 were found to fall in Group III, 27 in Group I, 5 in Group II and 2 in Group IV.

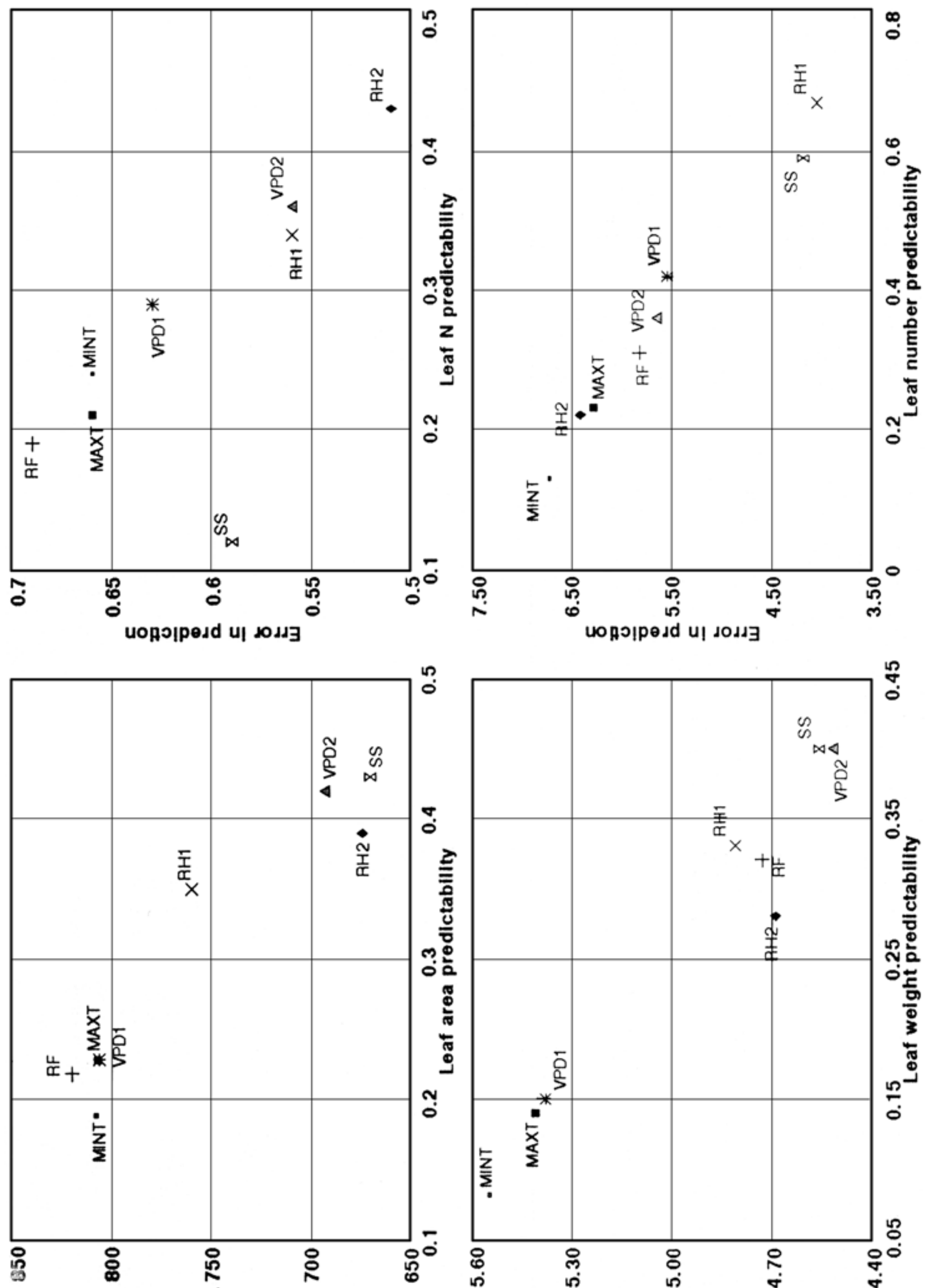

Figure 1: Influence of weather variables on predictability and error in prediction of leaf area, leaf N, leaf weight and leaf number in sunflower

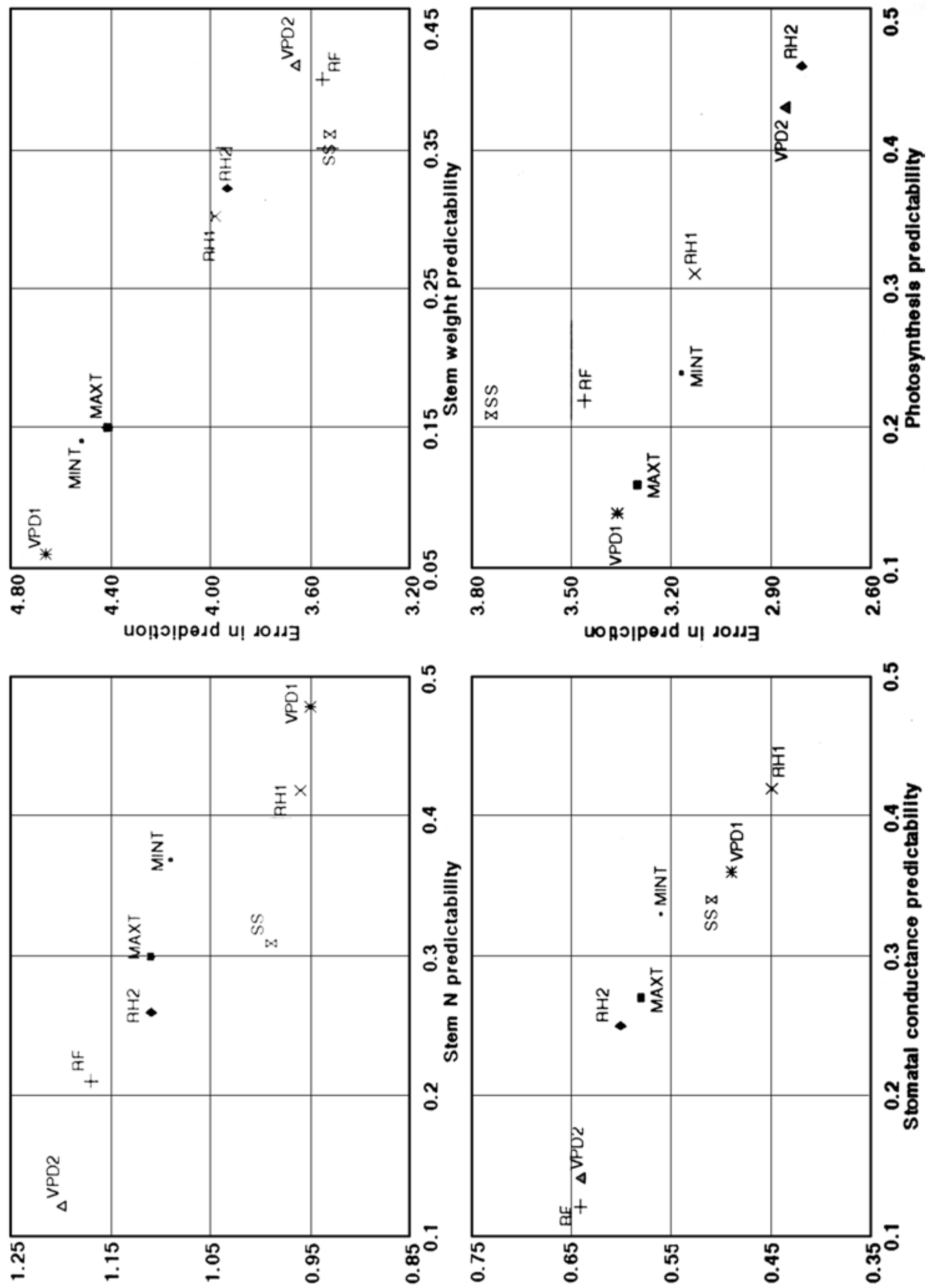

Figure 2: Influence of weather variables on predictability and error in prediction of stem N, stem weight, stomatal conductance and photosynthesis in sunflower

All plant traits were significantly predictable with minimal error through relative humidity at 7 AM (except leaf area) followed by sunshine hours (except leaf N and photosynthesis), relative humidity and vapor pressure deficit at 2 PM (except leaf number, stem N and stomatal conductance) in Group I. The effects of rainfall on leaf and stem weight, and vapor pressure deficit at 7 AM on stem N and stomatal conductance were also found to fall in Group I. The weather influences on plant traits falling in group I would also indicate the consistency of traits since the errors in their prediction are the lowest in this group. The influences of weather variables on the remaining plant traits were found to be either non-significant or they occurred with a high prediction error in the 6 years of study. Thus the study has given scope for quantifying the influences of weather variables on plant traits as measured by the predictability of traits, apart from identifying the traits which are consistent over a period of time as measured by the errors in prediction.

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PREVISIÓN DEL DESARROLLO DE PLANTACIONES DE GIRASOL, CULTIVADO EN EL CULTIVO SECO EN EL SUELO TIPO ALFISOL, DEPENDIENTE DE LAS CONDICIONES DE TIEMPO

RESUMEN

A base de los datos sobre las variables de tiempo y las características de las plantas recolectadas en los ensayos de campo, con 7 genotipos de girasol, cultivados durante 6 temporadas *karif* (1994-1999) en las condiciones de cultivo seco, en el suelo tipo alfisol, a base de las características medidas de las plantas, en este estudio se ha intentado prever el crecimiento de las plantas e identificar las variables de tiempo, que han tenido una significante influencia en el crecimiento de las plantas. Los parámetros de regresión, como la previsibilidad (R^2) y error de previsión (σ), han sido deducidos para valorar la influencia de precipitación atmosférica, número de horas de sol, temperatura máxima y mínima, humedad relativa del aire y del déficit hídrico a las 7 de la mañana y a las 2 de la tarde, en el contenido de nitrógeno en la hoja, superficie de la hoja, peso de la hoja, número de hojas, permeabilidad de estomas, fotosíntesis, peso del tallo y contenido de nitrógeno en el tallo, 30, 45 y 60 días después de la siembra. Fue determinado que existían las influencias positivas y significantes (i) del número de horas de sol, temperatura mínima, humedad relativa del aire y el déficit hídrico a las 7 de mañana, en conductibilidad de estomas, (ii) déficit hídrico, a las 2 de la tarde, a la fotosíntesis, tanto como las influencias negativas y significantes (i) de la humedad relativa del aire y del déficit hídrico a las 7 de la mañana en el contenido de nitrógeno en la hoja, (ii) temperatura mínima y el déficit hídrico a las 7 de la mañana en el número de hojas y (iii) la temperatura mínima, humedad relativa del aire y déficit hídrico a las 7 de la mañana, en el contenido de nitrógeno en el tallo. A base de la reseña gráfica 64 combinaciones de previsibilidad (R^2) y errores en previsión (σ) para las características de las plantas, influencias de las variables de tiempo, se han dividido en 4 grupos, alta R^2 y baja σ (Grupo I), alta R^2 y alta σ (Grupo II), baja R^2 y alta σ (Grupo III) y baja R^2 y baja σ (Grupo IV). De 64 pares de variables de tiempo y de plantas, 30 se encontraban en el Grupo III, 27 en el Grupo I, 5 en el Grupo II y 2 en el Grupo IV. Todas las características de las plantas estaban significativamente previsibles, con un error mínimo, en relación con la humedad relativa del aire a las 7 de la mañana (con excepción de la superficie de la hoja), número de horas de sol (con excepción del contenido de N en la hoja y fotosíntesis), la humedad relativa del aire y el déficit hídrico a las 2 de la tarde (con excepción del número de hojas, contenido de N en el tallo y conductibilidad de estomas) en el Grupo I. También se notó una significante influencia de las precipitaciones atmosféricas en el peso de la hoja y del tallo y el déficit hídrico a las 7 de la mañana, en el contenido de N en el tallo y conductibilidad de estomas. Las influencias de las variables de tiempo en otras características de las plantas durante 6 años de investigación, o eran insignificantes, o se presentaban con alto error de previsión.

PRÉVISIONS DE CROISSANCE POUR LE TOURNESOL CULTIVÉ SUR UN SOL DE TYPE ALFISOL ET DANS DES CONDITIONS MÉTÉOROLOGIQUES SPÉCIFIQUES

RÉSUMÉ

D'après une évaluation de leurs différentes caractéristiques, une tentative a été faite pour prévoir la croissance des plantes et pour identifier les variables de températures ayant une influence significative sur ce processus. Les données de base utilisées étaient les variables de la température et les caractéristiques des plantes recueillies dans des expériences effectuées sur 7 génotypes de tournesol cultivés dans les champs au cours de 6 saisons de *kharif* (1994-1999) dans les conditions d'un sol de type alfisol alimenté par la pluie. Des paramètres de régression tels que la prévisibilité (R^2) et l'erreur de prédiction (ó) ont été déduits pour que puisse être évaluée l'influence des précipitations, du nombre d'heures d'ensoleillement, des températures maximale et minimale, de l'humidité relative de l'air et du manque d'eau à 7 heures et à 14 heures sur le contenu d'azote dans la feuille, la surface de la feuille, le poids de la

feuille, le nombre de feuilles, la perméabilité des stomates, la photosynthèse, le poids de la tige et le contenu d'azote dans la tige 30, 40 et 60 jours après les semailles. Il a été établi qu'il existait une influence positive et importante (i) pour ce qui est du nombre d'heures d'ensoleillement, de la température minimale, de l'humidité relative de l'air et du manque d'eau à 7 heures sur la perméabilité des stomates, (ii) du manque d'eau à 14 heures sur la photosynthèse, ainsi qu'une influence négative et importante (i) de l'humidité relative de l'air et du manque d'eau à 7 heures sur le contenu d'azote dans la feuille, (ii) de la température minimale et du manque d'eau à 7 heures sur le nombre de feuilles et (iii) de la température minimale, de l'humidité relative de l'air et du manque d'eau à 7 heures sur le contenu d'azote dans la tige. Selon une représentation graphique de 64 combinaisons de prédiction (R^2) et d'erreur de prédiction (ó) pour les caractéristiques des plantes, les effets des variables de températures ont été divisés en 4 groupes, R^2 élevée et ó faible (Groupe I), R^2 élevée et ó élevée (Groupe II), R^2 faible et ó élevée (Groupe III) et R^2 faible et ó faible (Groupe IV). Des 64 paires de variables de température et de plantes, 30 faisaient partie du Groupe III, 27 du Groupe I, 5 du Groupe II et 2 du groupe IV. Toutes les caractéristiques des plantes étaient significativement prévisibles avec risque d'erreur minimale par rapport à l'humidité relative de l'air à 7 heures (sauf pour ce qui est de la surface de la feuille), le nombre d'heures d'ensoleillement (sauf pour ce qui est du contenu d'azote dans la liste et la photosynthèse), l'humidité relative de l'air et le manque d'eau à 14 heures (sauf pour ce qui est du nombre de feuilles, le contenu d'azote dans la tige et la perméabilité des stomates) dans le Groupe I. De même , pour ce qui concerne les précipitations, une influence significative a été remarquée sur le poids des feuilles et de la tige et pour ce qui est du manque d'eau à 7 heures, sur le contenu d'azote dans la tige et la perméabilité des stomates. L'influence des variables de température sur les autres caractéristiques des plantes au cours de 6 ans d'étude s'est montrée non significative ou a montré un niveau élevé d'erreur de prédiction.