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Use of agrometeorological indices for suitable sowing time of wheat under South Saurashtra Agroclimatic Zone of Gujarat

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ABSTRACT

The various agrometeorological thermal, and radiation use efficiency indices were used to identify the appropriate sowing time for wheat at Junagadh. The results revealed that under normal sowing condition the crop accumulated higher amount of heat units than late sown conditions. The RUE and HUEs were also higher for earlier sowings than later sowings. Thus the study suggested that the appropriate time of sowing for wheat is 15th Nov to 25th Nov for getting higher and stable yield of wheat under South Saurashtra Agroclimatic Zone of Gujarat.

Key words : Sowing time, heat indices, HUE, RUE, Wheat, Gujarat.

In India wheat is the most important irrigated crop in the semi-arid regions grown during the winter season. The best adaptation of the crop is in areas of moderate temperature under sub-humid to semi-arid climates. The cool weather during vegetative period and warm weather for maturity are ideal requirements for wheat (Mavi, 1986). Gujarat, which comes under the Central Zone, amongst the five Agroclimatic Wheat Zones of India, is second in productivity following the North Zone. The crop is grown in almost all districts of Gujarat among which Junagadh district ranks first in productivity (3076 kg ha^{-1}).

Agrometeorogical application of temperature effect on plant is the heat unit concept which has been variously applied to correlate phenological development in crops to predict sowing and maturity dates (Mills, 1964; Nuttonson, 1955). Apart from this, the radiation use efficiency (RUE) and heat use efficiency (HUE) were widely used in understanding energy use of crops (Rao et al, 1999 and Sharma et al, 2000). Some modified GDDs such as PTU, HTU, EDD, were employed because air temperature is not the only factor influencing growth and yield of crops.

Dependence of plant processes on its thermal and photo-thermal environments as envisaged in the heat unit concept implies that a plant must require some amount of heat in order to reach various stages of development (Chakravarty and Sastry, 1982). Wheat is a thermo sensitive, photo insensitive and long day plant. In India wheat is a rabi (winter) crop sown from October-December and harvested from February-May in different wheat regions of the country. Several workers (Agarawal et al, 1999, Goswami et al, 2003 and Mallick et al, 2006) have worked out the heat unit requirement for different phenophases of wheat cultivars. Meena and Dahema (2004) and Dhaliwal et al (2005) used the Agrometeorological indices for deciding sowing time of groundnut under irrigated condition of Western Rajasthan and for forecasting of mustard aphids respectively. In this paper the agrometeorological indices, radiation and heat use efficiencies were used to identify suitable sowing time of wheat under South Saurashtra Agroclimatic Zone of Gujarat.

MATERIAL AND METHODS

The data employed in this investigation pertains to Junagadh (21° 30'N Lat, 70° 30'E Long. 61.0m amsl) where experiments were conducted with four dates of sowing (D1= 2nd week of November, D2 = 1st week of December, D3 = 3rd week of December, and D4 = 1st week of January), in a split plot design with four replications using sixteen advanced varieties namely, GW 273, GW 275, GW 190(C), GW 1128(D), GW1129(D), Lov-1(C), Raj 1555(C), HI 8494(D), HI 1440, HI 8591, GW173(C), GW 279, GW 337, HI 1418, DL 788-2(C), MP 4010(I).

Five years crop data from 1995-96 to 2002-03 (except 1998-99, 1999-00 and 2001-02) and the concurrent weather data from the adjoining observatory were collected and used in this study. Different phenological stages such as crown root initiation (CRI), tillering, booting, flowering, milking, dough and maturity stages were identified.

Growing degree days (GDD), Photothermal unit (PTU), Heliothermal unit(HTU), Energy degree day (EDD) were calculated employing standard formula (Sastry and Chakravarty, 1982) using 5°c as base temperature for wheat (Nuttonson,1955). The energy degree unit was worked out by multiplying the unadjusted GDD for a day with the corresponding daily incident solar radiation value (Rs) for the same day. The Rs and PAR were as described by Rao et al (1999).

The heat use efficiency (HUE) in kg ha^{-1} day°C^{-1} was calculated in yield and biomass basis, by dividing total yield or biomass with accumulated agrometeorological indices such as GDD, HTU, PTU, EDD, PAR and RUE in g MJ^{-1} was calculated by dividing biomass (gm^{-2}) with cumulative PAR (MJ m^{-2}).

Correlation coefficients between yield and phenophasic heat indices were calculated and stepwise regression analysis was carried out to find out the significance of heat index and develop a regression model to predict yield of wheat.

RESULTS AND DISCUSSION

Effect of sowing time on yield of wheat

The data on wheat yield presented in Table-1 reveal that the earlier date of sowing gave higher yields than the delayed sowing with the highest yield (4195 kg ha^{-1}) recorded by the first date of sowing (D1). The lower standard deviation and the coefficient of variation of yield under normal sowing time than late sown times indicate the congenial weather conditions for better and stable yields.

Agrometeorological indices

The accumulated heat units for various growth stages under different sowing times presented in Table 2 (A, B, C, D & E) indicate that all the heat units derived from various agrometeorological indices using different weather parameters (such as temperature alone, temperature and BSS, temperature and ABSS, temperature and Rs) increased during CRI, tillering and booting stages and decreased during flowering and milking stages of the crop. In the post-anthesis phase (i e dough and maturity stages) the accumulated heat units decreased under late sowing time (D3). The GDD for entire crop growing period decreased with the subsequent delay in sowing, where as HTU, PTU, EDD and PAR were decreased up to late sowing time (D_3) and then increased under very late sowing (D_4) condition.

Radiation and heat use efficiencies.

The radiation use efficiency and heat use efficiency for different years and various dates of sowing are presented in Table 3. The results indicated that the RUE is highest for first date of sowing (D_1) in all the years. The mean RUE varied from 0.94 g MJ^{-1} to 0.63 g MJ^{-1} with the highest for first date of sowing. Similarly the HUE in various years were different for early and late sowing times. The mean HUE in kg ha^{-1} $^{0}day^{-1}$ varied from 2.21 for normal date of sowing to 1.27 for very late sowing. The HUE in g m^{-2} ^{0}day followed the same trend. The results are in conformity with the findings of Rao et al (1999) and Sharma et al (2000).

The thermal use efficiency calculated dividing yield (kg ha^{-1}) with total thermal units at the end of the season for different dates of sowing are presented in Table 4. The results indicated that the highest values of thermal efficiencies were recorded for normal sowing time.

Agrometeorological indices and yield

The correlation coefficient between yield and phenostagewise heat units for different sowing conditions presented in Table 5 revealed that EDD showed significant and positive correlation with crop yield during CRI, tillering and booting stages under normal sown condition (D_1). It indicated that the grain yield was dependent on the cumulative energy degree days at these stages. It was also observed that the GDD, PTU and EDD showed a significant

Table 1 : Wheat yield (kg ha^{-1}) for four sowing times in different years at Junagadh

Year	Sowing times			
	D1	D2	D3	D4
1995-96	-	-	3103	2317
1996-97	4109	2877	2815	2434
1997-98	4101	2970	3139	2448
2000-01	4516	3845	-	-
2002-03	3994	3300	3128	1594
Mean	4180.0	3248.0	3046.3	2198.3
SD	230.05	437.43	154.90	407.09
CV%	5.5	13.5	5.1	18.5

Table 2 : Accumulated agrometeorological indices for various growth stages under different sowing times.

Sowing time	CRI	Tillering	Booting	Flowering	Milking	Dough	Maturity	Total
(A) Growing degree day								
D1	396	331	245	233	170	237	396	2008
D2	364	313	234	243	170	255	364	1943
D3	343	329	159	216	154	189	343	1733
D4	348	226	175	254	212	178	348	1741
(B) Heliothermal unit								
D1	2884	2134	1515	1707	1371	1889	2884	14384
D2	2356	2052	1772	1926	1424	2346	2356	14232
D3	2270	1447	1125	2461	1240	1580	2270	12393
D4	2398	1676	1445	2184	2068	1637	2398	13806
(C) Photothermal unit								
D1	4411	3612	2680	2563	1890	2728	4411	22295
D2	3913	3426	2572	2773	2096	2985	3963	21728
D3	3735	2504	1746	3522	1774	2181	3735	19197
D4	3817	2530	1988	2940	2506	2123	3817	19721
(D) Energy degree day								
D1	6674	5059	3817	3861	2988	4573	6674	33646
D2	5564	4934	3923	4411	3459	5268	5564	33123
D3	5278	3548	2599	5548	2964	3702	5278	28917
D4	5582	3934	3271	5025	4397	3887	5582	31678
(E) Photosynthetically Active Radiation								
D1	177	146	117	125	88	132	177	962
D2	162	150	129	130	96	133	162	962
D3	154	107	81	176	85	98	154	855
D4	169	122	93	139	109	87	169	

Table 3 : Radiation use efficiency and Heat use efficiency of wheat during different growing environments in different years.

Year	Radiation use efficiency (g MJ^{-1})				Heat use efficiency (kg ha^{-1} deg day^{-1})				Heat use efficiency (g m^{-2} deg.day^{-1})			
	D1	D2	D3	D4	D1	D2	D3	D4	D1	D2	D3	D4
1995-96	-	-	0.81	0.68	-	-	1.91	1.45	-	-	0.42	0.35
1996-97	0.91	0.81	0.90	0.84	2.26	1.73	1.82	1.42	0.51	0.45	0.51	0.45
1997-98	0.95	0.80	0.40	0.23	2.28	1.62	1.54	1.19	0.52	0.45	0.23	0.13
2000-01	0.99	0.91	-	-	2.17	1.99	-	-	0.44	0.42	-	-
2002-03	0.91	0.89	0.90	0.75	2.13	1.64	1.59	1.00	0.17	0.12	0.39	0.34

Table 4 : Thermal use efficiency of wheat under different sowing times at Junagadh.

Sowing time	GDD	HTU	PTU	EDD	PAR
D1	2.09	0.29	0.19	0.12	4.36
D2	1.67	0.23	0.15	0.10	3.38
D3	1.66	0.24	0.16	0.10	3.56
D4	1.26	0.16	0.11	0.07	2.47

Table 5 : Correlation coefficients between wheat yield and phenophasic heat indices for normal and late sown condition.

stage	GDD	HTU	PTU	EDD	PAR
Normal Sown Condition					
CRI	0.633	0.297	0.686	0.854**	0.202
Tillering	0.566	0.086	0.594	0.748*	-0.060
Booting	0.601	-0.039	0.620	0.803*	-0.266
Flowering	0.507	-0.140	0.496	0.670	-0.219
Milking	0.448	-0.153	0.418	0.452	-0.303
Dough	0.432	-0.310	0.367	-0.177	-0.283
Maturity	0.540	-0.107	0.469	0.164	-0.036
Late Sown Condition					
CRI	-0.828**	-0.410	-0.834**	-0.851**	-0.598
Tillering	-0.774**	-0.228	-0.781**	-0.776**	-0.443
Booting	-0.759**	-0.213	-0.754*	-0.707*	-0.357
Flowering	-0.649*	-0.129	-0.690*	-0.839**	-0.137
Milking	-0.643*	-0.123	-0.653*	-0.623	-0.109
Dough	-0.608	-0.183	-0.623	-0.592	-0.095
Maturity	-0.494	0.167	-0.520	-0.545	-0.012

*, ** Significant at 5% and 1% levels respectively

and negative correlation with crop yields during first five stages except at the post-anthesis phase (dough and maturity). This indicated that the grain yields decreases with the increase in temperature, day length and radiant energy due to delay in sowing time.

The regression equations developed for prediction by stepwise regression analysis were highly related with normal sown condition ($R^2 = 0.968$) as compared to late sown condition (0.886).

As per the stepwise regression analysis the various models were developed for different heat indices and sowing conditions, which are given below.

Normal sown condition

$$Y = -14128.7 + 0.833\,X_1 + 0.295\,X_2 + 0.261\,X_3 \qquad R^2 = 0.968$$

Where, Y = Predicted yield (kg ha^{-1})

X1, X2, X3, = EDD at CRI, flowering and booting stages respectively

Late sown condition

$$Y = 12969.967 - 27.513\,Xc_1 \qquad R^2 = 0.685$$

$$Y = 13067.41 - 2.542\,Xc_2 \qquad R^2 = 0.695$$

$$Y = 21934.88 - 1.8\,Xc_3 - 0.348\,Xc_4 \qquad R^2 = 0.886$$

Where, Xc_1 = GDD at CRI Stage Xc_2 = PTU at CRI Stage, Xc_3 = EDD at CRI Stage, Xc_4 = EDD at flowering stage

From the R^2 value it was evident that validity of prediction equation for accumulated EDD under normal sowing condition (0.968) is higher than the R^2 value of late sown correlation (0.886).

CONCLUSION

On the basis of the above results it can be concluded that sowing of wheat can be done during 15[th] to 25[th] November in south Saurashtra Agroclimatic Zone based on thermal indices and thermal use efficiencies for higher productivity and stable production.

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