The Relationship Between Weather Parameters During Developmental Phase and Fruit Attributes and Yield of Peanut

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ABSTRACT

High variation in pod yield of groundnut was observed in winter planted irrigated peanut, depending on the time of planting. A field experiment was conducted with different dates of planting starting from beginning of the winter until end of the winter at 15 d intervals. Crop developmental stages were divided into three stages: vegetative, reproductive, and maturity. Weather parameters like maximum temperature, morning and evening relative humidity, sunshine hours, and evaporation were recorded from the observatory adjacent to the experimental field. Simple correlations and step down regression analyses were carried out between weather parameters in development phase and fruit attributes, pod yield, and harvest index. The results revealed that fruit attributes like hundred kernel weight, shelling percentage, and harvest index were significantly and negatively correlated with minimum temperature which prevailed over pod filling phase, accounting for 83.0, 94.8, and 82.8% variations respectively (R^2 = 0.830, 0.948, and 0.828), while haulm yield was significantly and positively correlated with minimum temperature which prevailed during pod filling phase, accounting for 82.1% variation in haulm yield (R^2 = 0.821). Pod growth rate and pod yield were significantly and positively correlated with diurnal variation in temperature, accounting for 63.5 and 69.0% variations respectively (R^2 = 0.635 and 0.690). The relationship between weather parameters, fruit attributes, and pod yield was established through a set of regression equations.

Key Words: *Arachis hypogaea*, Air temperature, fruit attributes, yield.

Peanut (*Arachis hypogaea* L.) is an important food and cash crop in the semi-arid tropics. Earlier studies on peanut showed that rate of plant development is predominantly influenced by temperature but is insensitive to water stress (Leong and Ong 1983). Others reported that 28 to 30 C is the optimum temperature for leaf and stem growth up to flowering, but a substantially lower optimum temperature exists for pod growth between 20 and 24 C. Highest maximum temperature, especially above 33 C during pod development and maturity phases was known to depress the yield through its effect on pollen viability (Prasad and Reddy 1990). Dry matter partitioning to stems, leaves, and pods of peanut is a function of mean air temperature. The ratio of pod to shoot weight was greatest at a mean temperature of 22 C and decreased from 0.28 to 0.04 when temperatures increased to 31 C (Org 1984). The partitioning of dry matter to pods would therefore be expected to decrease as temperatures increase (Cox 1979).

Detailed process based mechanistic models like PEANUTGRO and APSIM are available to predict growth, development, and yield of peanut. However, many parameters are needed to run these models. Hence, a simple model with minimum weather data is needed to suggest a suitable time of planting and to predict the yields from a winter crop.

Materials and Methods

The study was conducted on Alfisols of the Agri. Res. Stat., Reddipalli, Anantapur of Acharya N.G. Ranga Agri. Univ., India (14°–41ˉ N latitude, 77°–40ˉ E longitude and 350 m above mean sea level). Spanish bunch cv. Vemana peanuts were planted on the following seven dates: 1 Nov., 16 Nov., 1 Dec., 16 Dec., 31 Dec., 15 Jan., and 30 Jan. and recommended package of practices were adopted. At each planting date the plants were irrigated at irrigation water (50 mm)/cumulative pan evaporation (IW/CPE) ratios of 1.0, 0.8, and 0.6, replicating thrice. However, in this study the influence of weather parameters could be studied by comparing each planting date, irrigated at IW/CPE ratio of 1.0 since under these treatment combinations all crop management factors were maintained constant, thus leaving weather as the only variable. Weather data recorded at the adjacent observatory were used for the study.

To study the phenology, three peanut plants from each treatment were uprooted carefully from the area designated for sampling at 5 d intervals

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Table 1. Variation of phonological parameters of peanut (d) as influenced by planting dates.

Planting dates	Occurrence of phonological event (phase)			Total duration
	Vegetative	Reproductive	Pod filling	
		1994–95		
01 Nov.	33	25	64	122
16 Nov.	34	26	64	124
01 Dec.	37	19	55	111
16 Dec.	36	23	56	115
31 Dec.	35	21	59	115
15 Jan.	33	23	57	113
30 Jan.	29	28	51	108
		1995–96		
01 Nov.	28	25	67	120
16 Nov.	30	26	59	115
01 Dec.	33	23	54	110
16 Dec.	33	23	58	114
31 Dec.	33	24	61	118
15 Jan.	33	24	53	110
30 Jan.	30	27	55	112

and the following phonological events were recorded: emergence (VE), 50% flowering (R_1), pegging (R_2), seed initiation (R_5), pod development (R_6 to R_8). These phenophases were further grouped into three phases: vegetative (VE to R_1), reproductive (R_1 to R_5), and pod filling (R_5 to R_8) for studying crop-weather relationships (Krista Rao, 1996). The duration of each page is presented in Table 1.

Means of weather parameters such as maximum temperature (T_{max}), minimum temperature (T_{min}), Average temperature (Ï), diurnal variation in temperature (T_{DV}), relative humidity during morning (RH_m), relative humidity during afternoon (RH_a), and soil temperature at 5 cm (ST_5) and 10 cm (ST_{10}) (soil depths that prevailed over different phenophases) were calculated (Tables 2 and 3).

To study the influence of weather parameters on yield parameters, initially simple correlations were calculated between weather parameters that prevailed over different phenophases and yield parameters. After establishing the relationship between weather and yield parameters, step-down regression analysis was carried out with those weather parameters that had significant influence on yield parameters. By this analysis, the contribution of respective weather parameters that influenced the change in yield parameters was known and prediction equations were formulated.

Crop data such as pod growth rate from seed initiation to maturity (g m^{-2} d^{-1}), hundred kernel weight (g), shelling percentage, pod yield (kg ha^{-1}), haulm yield (kg ha^{-1}), and harvest index (%) were recorded as follows.

Pod Growth Rate. Pod growth rate (PGR) for the period from seed initiation to maturity (pod filling phase) was calculated using the formula

$$\mathrm{PGR} = \frac{W_2 - W_1}{t_2 - t_1}\ \mathrm{g\ m^{-2}\ d^{-1}} \tag{1}$$

where W_1 = weight of pods (g m^{-2}) at seed initiation, W_2 = weight of pods (g m^{-2}) at maturity, and ($t_2 - t_1$) = days between seed initiation and maturity.

Hundred Kernel Weight. Weight (g) of 100 randomly selected kernels from the representative samples were recorded for all treatments in all replications.

Shelling Percentage. Pods weighing 250 g from each treatment of all replications were shelled and kernel weights were recorded. Shelling percentage was obtained using the formula

$$\text{Shelling percentage} = \frac{\text{Weight of kernels}}{\text{Weight of pods}}\ \% \tag{2}$$

Pod Yield. Pods from the net plot (12.0 m^2) were stripped after uprooting, sun dried to constant weight and expressed in kg ha^{-1}.

Haulm Yield. After stripping the pods, the haulms from net plot area of each treatment of all replications were thoroughly sun dried to constant and expressed in kg ha^{-1}.

Harvest Index. Harvest index was computed using the formula

$$\text{Harvest index} = \frac{\text{Pod yield}\left(\mathrm{kg\ ha^{-1}}\right)}{\text{Biological yield}\left(\mathrm{kg\ ha^{-1}}\right)}\ \% \tag{3}$$

Table 2. Mean of weather parameters prevailed during different phenophases of groundnut under different planting dates during 1994–95.

Weather parameters	Sowing dates 01 Nov.	16 Nov.	01 Dec.	16 Dec.	31 Dec.	15 Jan.	30 Jan.
Vegetative phase (S1)							
1. Maximum temperature (°C)	28.5	29.1	28.3	28.3	29.2	30.6	32.9
2. Minimum temperature (°C)	14.9	12.0	11.5	13.2	12.7	12.8	14.2
3. Mean temperature (°C)	21.7	20.6	19.9	20.7	20.6	21.7	23.6
4. Diurnal temperature variation (°C)	13.6	17.1	16.8	15.1	15.7	17.8	18.7
5. Relative humidity I (%)	91	88	89	89	84	83	79
6. Relative humidity II (%)	60	42	42	46	41	38	33
7. Soil temperature at 5 cm (°C)	25.4	25.9	26.5	26.5	27.4	29.7	30.3
8. Soil temperature at 10 cm (°C)	25.2	25.5	25.6	26.6	26.7	28.8	30.1
Reproductive phase (S2)							
1. Maximum temperature (°C)	28.2	28.5	29.5	30.9	34.2	35.7	36.6
2. Minimum temperature (°C)	11.8	13.1	13.2	13.0	14.7	16.7	18.7
3. Mean temperature (°C)	20.0	20.8	21.4	22.0	24.4	26.2	27.2
4. Diurnal temperature variation (°C)	16.3	15.4	16.3	17.9	19.5	19.1	17.8
5. Relative humidity I (%)	90	88	85	84	74	70	64
6. Relative humidity II (%)	43	44	42	36	29	28	26
7. Soil temperature at 5 cm (°C)	25.9	26.4	27.8	28.9	29.8	30.9	32.8
8. Soil temperature at 10 cm (°C)	25.2	25.0	26.7	28.3	29.3	30.1	31.5
Pod filling phase (S3)							
1. Maximum temperature (°C)	31.8	33.6	34.5	36.1	37.2	38.2	37.7
2. Minimum temperature (°C)	14.0	14.8	15.6	17.4	19.1	20.6	21.2
3. Mean temperature (°C)	22.9	24.2	25.0	26.8	28.2	29.4	29.4
4. Diurnal temperature variation (°C)	17.9	18.7	18.9	18.7	18.1	17.5	16.6
5. Relative humidity I (%)	81	76	73	67	66	64	67
6. Relative humidity II (%)	36	32	30	28	28	30	35
7. Soil temperature at 5 cm (°C)	26.6	27.9	26.1	26.4	29.3	28.0	28.2
8. Soil temperature at 10 cm (°C)	26.9	28.0	29.4	29.8	32.8	32.2	32.9

Results and Discussion

Results of pooled analysis over two winter seasons showed significant variation in yields due to years, indicating the influence of weather on yield parameters of peanut. The crop planted in different dates was exposed to different thermal regimes during the growth period. During 1994 and 1995, minimum temperature during vegetative (S_1), reproductive (S_2) and pod filling (S_3) phases ranged from 11.5 to 14.9 C, 11.8 to 18.7 C, and 14.0 to 21.2 C respectively. During 1995 and 1996, the values ranged from 13.5 to 18.0 C; 12.4 to 18.3 C, and 13.8 to 21.1 C, coinciding with vegetative, reproductive, and pod filling phases, respectively.

Diurnal temperature range during 1994 and 1995 varied from 13.6 to 18.7 C; 15.4 to 19.5 C, and 16.6 to 18.9 C, coinciding with vegetative, reproductive, and pod filling phases. During 1995 and 1996, it ranged from 13.7 to 18.7 C in the vegetative phase; 16.1 to 20.9 C in the reproductive phase, and 17.9 to 19.8 C in the pod filling phase. The influence of weather parameters that prevailed over different phenophases on crop parameters are discussed in detail below.

Pod Growth Rate (PGR). PGR varied due to planting dates. In both years, crop planted from 1 to 31 Dec. (Table 2) had the highest PGR. Crop planted 1 Nov. and 1 Jan. recorded the lowest PGR in the first year, while in second year, 30 Jan. crop had the lowest PGR. It was significantly and negatively correlated with T_{max} and T_{min} which prevailed during the S_2 phase. However, it was significantly and positively correlated with T_{DV} which prevailed during the S_3 phase of peanut. Step-down regression analysis revealed that T_{DV} of the S_3 phase (T_{DV} S_3) alone had contributed for 69.0% variation (R^2 = 0.690) in PGR. The prediction equation was

$$PGR = 85.33 - 9.642T_{DV}S_3 + 0.2843T_{DV}S_3 \quad (4)$$

3.2 Hundred Kernel Weight (HKW) and Shelling Percentage (SP). Pooled analysis of data on HKW and SP revealed that all four dates of planting from 1 Nov. to 16 Dec. resulted in significantly higher HKW than in the later three plantings. Early plantings before 16 Dec. were on par and recorded significantly higher SP than the later four dates of planting (Table 4).

Table 3. Mean of weather parameters prevailed during different phenophases of groundnut under different planting dates during 1995–96.

Weather parameters	Sowing dates						
	01 Nov.	16 Nov.	01 Dec.	16 Dec.	31 Dec.	15 Jan.	30 Jan.
Vegetative phase (S1)							
1. Maximum temperature (°C)	31.7	30.8	29.9	30.2	30.9	31.8	32.9
2. Minimum temperature (°C)	18.0	15.4	13.6	13.9	13.5	13.5	14.2
3. Mean temperature (°C)	24.9	23.1	21.8	22.1	22.2	22.6	23.5
4. Diurnal temperature variation (°C)	13.7	15.4	16.4	16.3	17.4	18.2	18.7
5. Relative humidity I (%)	84	89	83	80	74	67	66
6. Relative humidity II (%)	47	46	46	44	38	34	32
7. Soil temperature at 5 cm (°C)	27.5	26.1	26.5	27.0	26.8	27.3	28.6
8. Soil temperature at 10 cm (°C)	27.6	25.8	25.6	26.0	25.9	26.3	28.1
Reproductive phase (S2)							
1. Maximum temperature (°C)	29.6	30.0	31.4	31.4	33.6	36.0	38.9
2. Minimum temperature (°C)	13.0	13.9	13.6	12.4	15.2	15.1	18.3
3. Mean temperature (°C)	21.3	22.0	22.5	21.9	24.4	25.5	28.6
4. Diurnal temperature variation (°C)	16.6	16.1	17.8	19.0	18.4	20.9	20.6
5. Relative humidity I (%)	88	88	84	80	77	71	61
6. Relative humidity II (%)	46	44	35	32	34	26	20
7. Soil temperature at 5 cm (°C)	25.7	27.0	27.8	26.7	28.7	30.0	32.7
8. Soil temperature at 10 cm (°C)	25.2	25.8	26.3	26.1	27.9	28.9	31.2
Pod filling phase (S3)							
1. Maximum temperature (°C)	32.4	33.0	33.9	36.7	37.9	38.5	38.9
2. Minimum temperature (°C)	13.8	14.1	14.0	17.3	19.6	20.4	21.1
3. Mean temperature (°C)	23.1	23.6	23.9	27.0	28.7	29.4	30.0
4. Diurnal temperature variation (°C)	18.6	19.0	19.8	19.4	18.3	18.1	17.9
5. Relative humidity I (%)	80	78	76	70	66	66	65
6. Relative humidity II (%)	33	31	29	26	25	25	25
7. Soil temperature at 5 cm (°C)	26.6	28.3	25.6	26.5	28.6	28.6	29.7
8. Soil temperature at 10 cm (°C)	26.7	27.4	28.9	29.7	31.9	32.5	33.8

Analyses revealed significant but negative correlation between all weather parameters (except RH_m and RH_a), which prevailed during the S_2 phase and HKW and SP. The relationship between weather parameters that prevailed during the S_3 phase and yield parameters showed that either decrease in T_{max}, T_{min}, T_{mean}, and soil temperature of both the depths or increase in T_{DV} and RH_m significantly increased the HKW and SP. However, results of step-down regression analysis revealed that considerable variation in HKW and SP were accounted for by T_{min} during the S_3 phase (T_{min} S_3) only. It alone contributed for 83.0 and 94.8% the variation ($R^2 = 0.830$ and 0.948) in HKW and SP,

Table 4. Yield attributes and yield as influenced by planting dates.

Planting dates	Pod growth rate[a]		Pooled		
	1994–95	1995–96	100kernel weight	Shelling	Pod yield
	($g\ m^{-2}\ d^{-1}$)		**(g)**	**%**	**(kg/ha)**
01 Nov.	3.6	3.8	42.5	77.0	2030
16 Nov.	4.4	3.9	40.7	75.7	2250
01 Dec.	5.6	5.7	41.3	75.1	2480
16 Dec.	4.7	5.6	35.9	72.1	2340
31 Dec.	4.2	4.4	31.6	68.1	2140
15 Jan.	3.6	4.0	31.1	64.9	2010
30 Jan.	3.7	3.6	28.2	59.1	1570
Mean	4.3	4.4	35.9	70.3	2120
SEm±	—	—	1.93	0.65	105.28
CD (P = 0.05)	—	—	6.67	2.23	364.30

[a]Data not analyzed statistically.

Table 5. Haulm yield and harvest index as influenced by planting dates.

Planting dates	Haulm yield		Harvest index	
	1994–95	1995–96	1994–95	1995–96
	(kg ha^{-1})		%	
0 1Nov.	2755	3327	41.1	39.1
16 Nov.	3210	3535	44.1	35.8
01 Dec.	2813	3427	46.3	42.5
16 Dec.	5178	5613	31.3	29.2
31 Dec.	5181	5654	29.7	27.0
15 Jan.	5061	7288	28.5	21.5
30 Jan.	6917	6579	18.0	19.9
Mean	4445	5060	34.1	30.7
SEm±	34.28	42.45	0.36	0.18
CD (P = 0.05)	105.65	130.83	1.12	0.55

respectively. The following prediction equations evolved.

$$HKW = 67.91 - 1.8460\ T_{min}S_3 \qquad (5)$$

$$SP = 18.14 + 8.297T_{min}\ S_3 - 0.270T_{min}\ S_3^2 \qquad (6)$$

All the four dates of planting from 1 Nov. to 16 Dec. resulted in higher HKW and SP compared to the later three dates of plantings (Bell *et al.* 1987; Prasad and Reddy 1990). Both these yield attributes were significantly low due to higher T_{min} during the S_3 phase as evident from regression analysis (Figs. 1 and 2). The crop planted from 1 Nov. to 16 Dec. recorded higher HKW and SP due to optimum T_{min} ranging from 13.8 to 17.4 C during the S_3 phase (Ntare *et al.* 1993). High T_{min} (19.1 to 21.2 C) due to 31 Dec. to January plantings were not conducive to energy reserves. Low availability and reduced translocation of photosynthates to developing pods under high temperatures might have resulted in poor pod filling, leading to reduced HKW and SP.

Pod Yield (Y_p). Pooled analysis of Y_p over 2 yr (Table 2) brought about significant variations due to planting dates. Six planting dates 1 Nov. to 15 Jan. at 15 d intervals resulted in comparable yields. The latest planted crop on 30 Jan. recorded significantly less yield compared with the earlier six planting dates. Pooled analysis showed 62.7% increase in pod yield with the 16 Dec. crop over the latest planted crop on 30 Jan.

T_{max}, ST_5 and ST_{10} that prevailed during the S_1 phase had significantly and positively correlated with pod yields. During the S_2 phase, pod yield (Y_p) was significantly and positively correlated with RH_m, but negatively correlated with T_{min}, T_{max}, T_{mean}, ST_5, and ST_{10} of the weather parameters which prevailed during the S_3 phase. TD_V had significant positive correlation with pod yield, while T_{min} and ST_5 were negatively correlated. However, the results of step-down regression

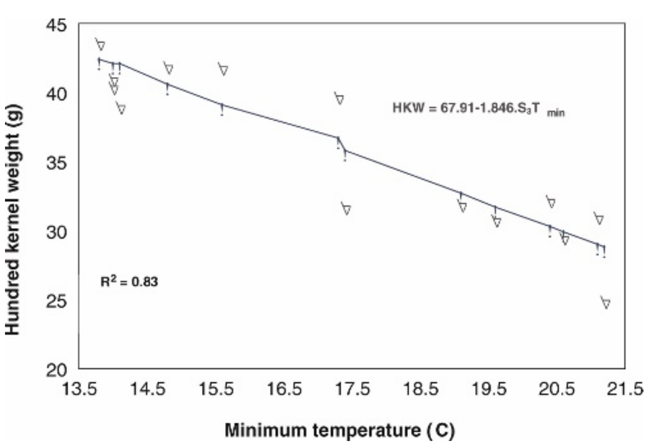

Fig. 1. Relationship between minimum temperature during the pod filling phase and 100 kernel weight of peanut cv. Vemana sown at varied dates in the winter.

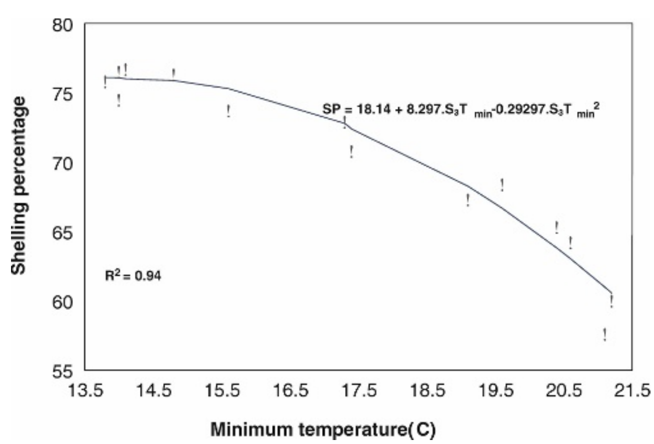

Fig. 2. Relationship between minimum temperature during the pod filling phase and shelling percentages of peanut cv. Vemana planted at varied dates in the winter.

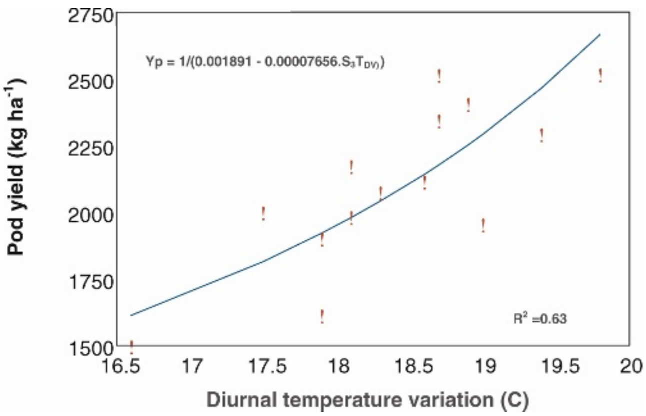

Fig. 3. Relationship between diurnal temperature variation during the pod filling phase and pod yield of peanut cv. Vemana planted at varied dates in the winter.

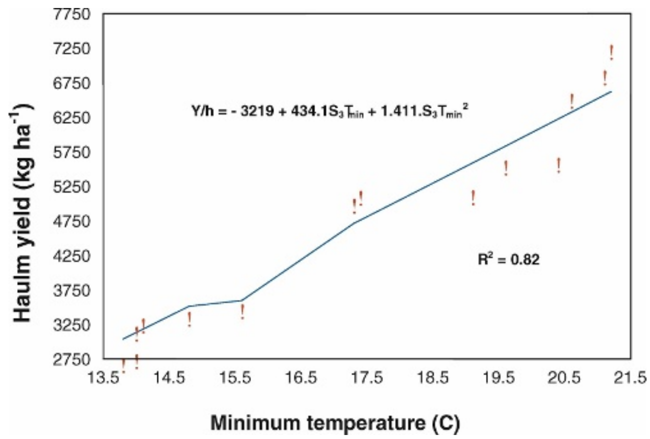

Fig. 4. Relationship between minimum temperature during the pod filling phase and haulm yield of peanut cv. Vemana planted at varied dates at the winter.

analysis indicated that the T_{DV} S_3 contributed for 63.5% variation ($R^2 = 0.635$) in Y_p. The following prediction equation was formulated.

$$Y_p = 1/(0.001891 - 0.0000\,7656 T_{DV} S_3) \quad (7)$$

Variation in pod yields due to planting dates were mainly due to differences in T_{DV} (Fig. 3) and their effect on various physiological processes particularly portioning of dry matter and respiration. T_{DV} ranging from 17.9 to 19.8 C with T_{min} from 13.8 to 19.6 C during the S_3 phase were optimum for higher pod yields. Higher T_{min} with January plantings might have exhausted the energy reserves during the respirating process, leading to poor pod yields. Adverse effects of night temperatures on peanut pod yield were also reported by several researchers (Elangoan and Gopalaswamy 1976; Rao 1987; Prasad and Reddy 1990).

Haulm Yield (Y_h). There was significant variation in Y_h due to planting dates (Table 3). During 1994 and 1995, significantly higher Y_h was due to 30 Jan. planting. Crops planted 1 Nov. and 1 Dec. recorded the significantly lowest Y_h. There was a progressive increase in Y_h with early planting from 1 Nov. to the latest planting on 30 Jan. during the second year.

Correlation studies indicated that during all the three phases of peanut growth, either increase in T_{min}, T_{max}, T_{mean}, ST_5, and ST_{10} or decrease in RH_m and RH_a significantly increased the Y_h of peanut. However, the results of step-down regression analysis revealed that variation in Y_h was mainly due to T_{min} which prevailed during S_3 (T_{min} S_3) and it alone contributed to 82.1% variation in Y_h. The following prediction equation evolved.

$$Y_h = 3219 + 434.1 T_{min} S_3 + 1.411 T_{min} S_3^2 \quad (8)$$

Differences in Y_h increased as the plantings were delayed and temperatures increased (Fig. 4) at each successive stage of the crop. Regression analysis also indicated that increased T_{min} favored the Y_h without translocating the energy reserves into pods as reflected on HKW and SP.

Harvest Index (HI). In first year, the highest HI of 41.9% was due to the 16 Nov. planting and was significantly higher compared with other planting dates (Table 3). The lowest HI occurred on 30 Jan. A similar trend was followed even in the second year.

Correlation studies revealed similar results as per HKW and SP. T_{min} S_3 alone accounted for 82.8% variation ($R^2 = 0.828$) in HI. The prediction equation was

$$HI = 4.09 + 6.316 T_{min} S_3 - 0.2628 T_{min} S_3^2 \quad (9)$$

Variations in HI due to planting dates were significant in both years. Differences in HI due to planting dates are an indication of translocation efficiency as peanut has an indeterminate growth habit. There was an overlapping of vegetative and reproductive phases that results in the formation of actively growing stems and leaves that might have competed with pod formation and maturation for photosynthates. Hence, there might have been hindrance to the translocation to photosynthates to pods in the delayed plantings, leading to low HI with the late plantings of January (Fig. 5). This is evident from the influence of planting date on pod growth studies.

Conclusions

The results of this study indicated that different phenophases of peanut coincided with different

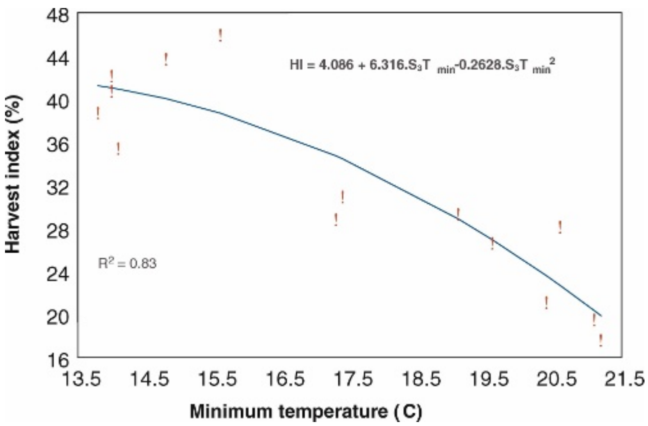

Fig. 5. Relationship between minimum temperature during the pod filling phase and harvest index of peanut cv. Vemana planted at varied dates in the winter.

climatic regimes due to different planting dates from 1 Nov. to 30 Jan.. Yield parameters were related with weather parameters during crop growth periods for all the planting dates to find an ideal climatic regime for improving the productivity of winter peanut on shallow Alfisols. From the results it is evident that peanut productivity during the winter season in India is primarily dictated by diurnal variation in temperature and minimum temperature during the pod filling phase. Diurnal variation in temperature ranging from 17.9 to 19.8 C with minimum temperature ranging from 13.8 to 19.6 C during the pod filling phase was optimum for higher pod yields as such, the hypothesis postulated that the development of peanut fruit is temperature-dependent has been proven. The objective of planting winter peanut should be such that it passes through optimum diurnal variation in temperature and minimum temperature during the pod filling phase.

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