Indian Journal of Agronomy **46** (4) : 712–720 (December 2001)

Influence of weather and soil-moisture regimes on winter groundnut (*Arachis hypogaea*) productivity

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Received: January 2001

ABSTRACT

An experiment was conducted during 1994–96 to identify an ideal time for sowing winter groundnut *(Arachis hypogaea* L.) to match the available water supply without subjecting the crop to terminal soil-moisture stress. High relative humidity during morning with early-sown crop (earlier than 31 December) significantly reduced the plant height. Total dry-matter production was positively and significantly influenced by the minimum temperature (T_{min}) during pod-filling phase (S_3), while the yield attributes were negatively influenced by T_{min} during S_3 phase. Dry-matter production of crop sown in November and December, even with irrigation schedule of 1.0 IW : CPE ratio was lower than that of late-sown crop irrigated at 0.8 and 0.6 IW : CPE ratio. Decrease in diurnal variation in temperature (<17.9°C) due to increase in minimum temperature (>19.6°C) reduced the translocation of photosynthates into pods, leading to reduced the pod yield with January sowing. The sub-optimal weather conditions during crop period with January sowings could not be mitigated by frequent irrigations (1.0 IW : CPE ratio), as such the ideal time for sowing winter groundnut was found to be 16 November to 16 December for Anantapur district of scarce rainfall zone in Andhra Pradesh.

Key words : Winter groundnut, Productivity, Weather, Soil moisture

Groundnut (*Arachis hypogaea* L.) is the important oilseed crop, meeting the needs of vegetable fat, protein, cattle feed and concentrated organic manure. The productivity of winter and summer sown groundnut is more than that of rainy season, since the major requirement of soil moisture is met through assured irrigations during winter and summer seasons. However, during winter and summer seasons also, its productivity mostly depends on weather conditions that prevail during crop-growth period which in turn depends on sowing time. The irrigation capacity of the wells

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goes down by March – April, thereby winter sown groundnut is subjected to terminal moisture stress. If the crop is sown early during winter season, the weather conditions may not be congenial to reap a good crop. Hence in-depth study is necessary to find out optimum time for sowing which allows the groundnut crop to pass through optimum weather conditions at different growth phases without subjecting the crop to terminal moisture stress.

MATERIALS AND METHODS

A field experiment was carried out during 1994–95 and 1995–96 during the winter season at Agricultural Research Station, Reddipalli (14°–41′ N, 77°–40′ E, and at an altitude of 350 m above mean sea-level in scarce rainfall zone of Andhra Pradesh.

The soil was shallow (20–25 cm), sandy loam, slightly alkaline (7.5 pH), low in available nitrogen (109.7 kg/ha), medium in available phosphorus (15.6 kg/ha) and potassium (176.7 kg/ha) with a bulk density of 1.45 g/cm^3. Available soil-moisture content in root zone depth (0 to 45 cm) is 6.93 with a field capacity of 10.59 and permanent wilting point of 3.66%.

The experiment was laid out in split-plot design with 21 treatment combinations, replicated thrice. The treatments included 7 dates of sowing 1 November, 16 November, 1 December, 16 December, 31 December, 15 January and 30 January as main plots and 3 irrigation schedules (IW : CPE ratios of 1.0, 0.8 and 0.6 with 5 cm depth of irrigation) as subplots. Spanish bunch 'Vemana' ('K 134') of 110 days duration during winter was used. Recommended package of practices were followed and prophylactic measures were taken against sucking pests.

Before imposing the treatments as per the irrigation schedules, 3 common irrigations were given, i.e. first irrigation prior to sowing and second 5 days after sowing to ensure good germination and adequate stand establishment. Later, crop was not irrigated up to 25 days after sowing. Third common irrigation was given to all treatments uniformly 25 days after sowing with 5 cm depth of irrigation water. Later, the crop was irrigated as per irrigation schedules. Weather data recorded in class A observatory situated in the adjoining field were made use of and mean of weather parameters during vegetative, (S_1), reproductive (S_2) and pod-filling phases(S_3), coinciding with sowing to 40 days after sowing, 41 to 60 days after sowing and 61 days after sowing to maturity, respectively, was calculated.

Groundnut plants in 0.3 m^2 (1.0 m × 0.3 m) were uprooted carefully at the end of each phenophase from the area ear marked for sampling. The influence of weather and irrigation schedules on plant height, crop-growth rate, total dry-matter production, 100-kernel weight, shelling percentage, pod yield and crop water-use efficiency were studied.

To study the influence of weather parameters on crop growth and yield parameters, initially simple correlations were worked out between weather parameters during S_1, S_2 and S_3 phases and the resultant crop growth and yield parameters at harvest. After establishing the relationship between weather and crop growth, step-down regression analysis was carried out considering those weather parameters that had significant influence. By this analysis, the contribution of respective weather parameter in bringing out the change in crop growth and yield parameters was known. Weather relations were worked out considering the data of 1.0 IW : CPE ratio of each sowing date so as to leave the weather as the only variable in bringing the change.

RESULTS AND DISCUSSION

Plant height

Dates of sowing and irrigation schedules influenced the plant height at harvest (Table 1). Interactions were significant in second year only. In both the years, the latest sown crop (30 January) was significantly taller than other dates of sowing. January sowings, in general, resulted in taller plants than than early sowings in November and December. Correlation study revealed (r=0.8739**) that either increase in diurnal variation in temperature (TDV) or decrease in relative humidity during morning (RH_m) of S_2 phase (r = 0.9245**) significantly increased the plant height at harvest. Step-down regression analysis showed that RH_m accounted for 88.9% variation (R_2 = 0.889), while this parameter in combination with TDV of S_2 phase accounted for 93.1% variation in plant height at harvest (R_2 = 0.931). As the RH_m for January-sown crop was less (61–71%) than that for early-sown crop, plants were taller with January sowings. High RH_m with early-sown crop before 31 December (74 – 90%) might have reduced the cell elongation in the internodal region, resulting in shorter plants.

In both the years, there was progressive and significant decrease in plant height with decrease in IW : CPE ratio from 1.0 to 0.6. Plant growth depends on cell division and cell expansion for which adequate water supply is essential (Singh and Singh, 1977). Hence plants were taller due to irrigation schedules at 1.0 IW : CPE ratio. Latest sowings resulted in taller plants with all the irrigation schedules. However, irrigation schedules could not exhibit marked change in plant height of November-sown crop.

Crop-growth rate

Crop-growth rate during pod-filling phase (S_3) was highest with 30 January-sown crop in 1994–95. In second year, 15 January-sown crop had highest crop-growth rate. November sowings had the lowest crop-growth rate (Table 1). This might be de to more mean air temperatures with late-sown crop (25.5–28.6°C) all through the crop period as against 20.0 – 22.0°C with November sowings. The results are in agreement with the findings of Yoshitaka Ono *et al.* (1974). The crop-growth rate during S_3 phase was significantly and positively correlated (r=0.5593*) with mean temperature (T_{mean}) and soil temperature (ST_5) at 5 cm soil depth (r= 0.6438*) prevailed over S_2 phase. Step-down regression analysis indicated that ST_5 prevailed during S_2 phase alone accounted for 41.5% variation (R_2=0.415) in crop-growth rate during S_3 phase. High ST_5 of January-sown crop (30-32°C) might have increased the crop-growth rate than crop sown in November (25.7 to 27.0°C). Groundnut crop is relatively sensitive to environment prior to pod filling. Early

Table 1. Influence of sowing dates and irrigation schedules on growth and yield attributes of winter groundnut at harvest

Treatment	Plant height (cm)		Crop growth rate during S_3 phase (g/m/day)*		Total dry-matter production (g/m^2)		Pooled	
	1994–95	1995–96	1994–95	1995–96	1994–95	1995–96	100-kernel weight (g)	Shelling (%)
Date of sowing								
1 November	12.0	16.4	4.40	4.72	363.8	452.4	40.0	75.4
16 November	11.9	13.5	4.73	5.70	406.6	446.7	37.9	73.8
1 December	13.0	15.5	5.68	6.71	435.3	476.7	36.3	73.7
16 December	15.7	19.6	7.58	6.80	523.7	507.6	33.6	70.6
31 December	17.0	17.0	5.94	6.40	481.6	522.5	29.5	66.6
15 January	19.7	22.0	7.58	8.10	599.7	597.4	29.1	64.3
30 January	22.0	24.3	14.04	6.30	840.2	521.7	26.2	59.5
CD (P=0.05)	0.65	1.00			25.92	24.20	6.67	2.23
Irrigation schedules (IW : CPE ratio)								
1.0	18.0	20.8	7.83	7.42	588.8	591.6	35.9	70.3
0.8	15.6	17.6	6.70	6.20	496.8	492.2	33.0	69.5
0.6	1401	16.3	6.92	5.50	505.4	436.9	30.9	67.6
CD (P=0.05)	0.51	0.52			14.06	15.58	1.61	NS
Interaction								
CD (P=0.05)	NS	1.59			42.07	40.81	2.05	NS

*Data not analysed statistically

vegetative phase appears to be more sensitive (Williams *et al.*, 1978). Hence weather parameters during S_2 hase influenced crop-growth rate. Irrigating the crop at lowest IW : CPE ratio of 0.6 recorded lowest crop-growth rate values than the other 2 ratios. This might be due to reduced rates of leaf initiation and leaf expansion (Ong, 1986).

Total dry-matter production

Dates of sowing, irrigation schedules and their interaction significantly affected the total dry matter at harvest in both the years (Table 1). The crop sown on 30 January and 15 January recorded significantly highest total dry-matter production during 1994–95 and 1995–96, respectively, while that in November and December resulted in significantly less total dry-matter production.

Variation in the rate of total dry-matter production was due to variation in minimum temperature (T_{min}) (r = 0.7144**) during S_3 phase, which accounted for 52.1% variation (R_2 = 0.521) in total dry-matter production. Ono and Ozaki (1974) also observed similar effect of temperature on total dry-matter production. Bell (1986) opined that in the absence of soil-moisture stress, temperature plays a dominant role.

The crop irrigated at IW : CPE ratio of 1.0 recorded the highest total dry-matter production. However, the differences due to 0.8 and 0.6 ratios were not significant in the first year. Adequate available soil moisture in the root zone depth of soil due to frequent irrigations might have improved the nutrient availability, thereby increasing cell division and cell expansion which in turn increased the total dry-matter production (Mallikarjuna Rao, 1990). Total dry-matter production with November and December sown crops even with irrigation schedule of 1.0 IW : CPE ratio was lower than that of the late-sown crop irrigated at 0.8 and 0.6 IW : CPE ratio. The results indicate that climatic factors play a dominant role in total dry-matter-production than irrigation scheduling.

100-kernel weight and shelling (%)

Pooled data on 100-kernel weight revealed significant variations due to dates of sowing, irrigation schedules and their interactions, while variation in shelling (%) was significant due to sowing dates only. All the dates of sowing, from 1 November being at par, recorded significantly higher 100- kernel weight than the other dates (Table 1). Similarly, first 3 dates of sowing, i.e. 1 November to 1 December, being at par recorded significantly higher shelling % than other dates.

There was no significant improvement in yield attributes due to increase in minimum temperature (T_{min}) during S_3 phase, as evident from correlation study and step-down regression analysis (Figs. 1 and 2). Decrease in T_{min} significantly increased the 100- kerned weight (r = 0.9321**) and shelling % (r = 0.9450**). The crop sown from 1 November to 16 December improved the yield attributes owing to optimum T_{min} ranging from 13.8 to 17.4°C during S_3 phase. The results are in accordance with the findings of Ntare *et al.* (1993). High minimum temperatures (19.1 to 21.2°C) during 31 December to January sowings were not conducive to food reserves. Low

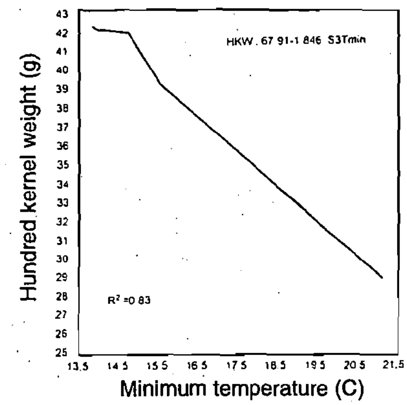

Fig. 1. Predicted 100-kernel weight (g) in response to minimum temperature

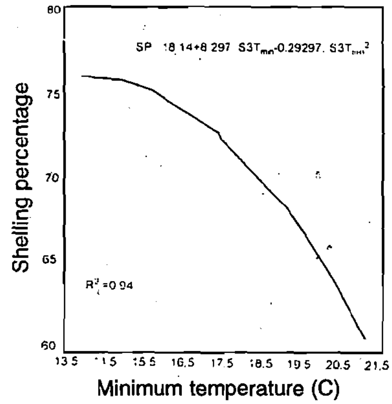

Fig. 2. Predicted shelling (%) in response to minimum temperature

availability and reduced translocation of photosynthates to developing pods under high temperatures might have resulted in poor pod filling, leading to low yield attributes.

Scheduling irrigation at 1.0 IW : CPE ratio significantly increased the 100-kernel weight while lowest ratio of 0.6 recorded less 100-kernel weight. Adequate available soil moisture might have largely contributed to proper pod filling, resulting in higher 100-kernel weight (Rami Reddy *et al.*, 1982; Patel *et al.*, 1995). Improvement in yield attributes was with early sowings from 1 November to December even with 0.6 IW : CPE ratio than that with higher IW

Table 2. Pooled pod yield (kg/ha) of winter groundnut as influenced by sowing dates and irrigation schedules

Date of sowing	IW : CPE ratio			
	1.0	0.8	0.6	**Mean**
1 November	2,026	1,779	1,570	1,792
16 November	2,253	1,972	1,570	1,931
1 December	2,480	2,035	1,556	2,024
16 December	2,336	2,038	1,766	2,047
31 December	2,142	1,915	1,523	1,860
16 January	2,009	1,670	1,505	1,728
30 January	1,573	1,194	1,007	1,258
Mean	2,117	1,800	1,500	
	Date	*Irrigation*	*D × I*	
CD (P=0.05)	364	308	NS	

: CPE ratio in later sowings. The results indicate dominate role of weather on crop performance than irrigation schedules.

Pod yield

Pooled analysis (Table 2) showed significant variations in pod yield due to dates of sowing, i.e. through weather and irrigation schedules. Six dates of sowing from 1 November to 15 January at 15 days interval resulted in comparable yields ranging from 2,047 to 1,728 kg/ha. The delayed sown crop on 30 January recorded significantly less yield compared with earlier 6 dates of sowing. Pooled analysis showed 62.7% increase in pod yield with 16 December-sown crop over crop sown on 30 January. During both the years, January sowings recorded less pod yields compared with early sowings. The results are in conformity with the findings of and Ntare *et al.* (1993).

Correlation studies and step-down regression analysis indicated significant and positive influence of diurnal variation in temperature (T_{dv}) during S_3 phase (r = 0.7923**) on pod yield of groundnut. Variations in pod yield due to sowing dates were mainly due to in T_{dv} and their effect on various physiological processes, particularly partitioning of dry matter. The T_{dv} ranging from 17.9 to 19.8°C with minimum temperatures ranging from 13.8 to 19.6°C during S_3 phase were optimum for higher pod yields. Decrease in T_{DV} due to increase in minimum temperature reduced the accumulation of photosynthates in pods as recorded with January sowings. These higher minimum temperatures (20.4–21.2°C) might have exhausted the food reserves during respirating process, leading to poor pod yields with January sowing (Vara Prasad and Ramakrishna Reddy, 1990). Scheduling irrigation at IW : CPE ratio of 1.0 resulted in significantly highest yield. Increase in pod yield (pooled) owing

Table 3. Crop water-use efficiency in winter groundnut as influenced by sowing dates and irrigation schedules

Treatment	1994–95				1995–96			
	IW : CPE ratio				IW : CPE ratio			
	1.0	0.8	0.6	Mean	1.0	0.8	0.6	Mean
1 November	4.76	4.13	3.69	4.19	5.11	4.67	4.75	4.84
16 November	6.04	5.63	4.51	5.39	4.55	4.44	4.43	4.47
1 December	5.65	4.94	3.31	4.63	5.69	5.16	4.50	5.08
16 December	5.52	4.98	4.46	4.99	5.38	4.95	4.61	5.12
31 December	4.88	4.72	3.84	4.48	4.49	4.15	4.07	4.24
15 January	4.38	3.96	3.78	4.04	4.34	4.02	3.60	3.99
30 January	3.06	2.73	2.25	2.68	3.54	2.86	2.82	3.07
Mean	4.90	4.44	3.69		4.73	4.37	4.11	

to IW : CPE ratio of 1.0 was 41.1 and 17.6% over IW : CPE ratio of 0.6 and 0.8 respectively. This was because of improvement in yield attributes because of adequate available soil moisture (Patel *et al.*, 1995).

Crop water-use efficiency

Crop water-use efficiency (Table 3) indicated considerable differences due to sowing dates and irrigation schedules. During 1994–95, the crop sown on 16 November recorded the highest value, followed by 16 December-sown crop. During 1995–96, the crop sown on 16 December had highest crop water-use efficiency. Late sowings had lowest values in both years. This might be due to loss of water through ET and adverse weather conditions leading to the drastic reduction in yield, thereby recording lowest crop water-use efficiency.

Crop water-use efficiency increased with increase in IW : CPE ratio from 0.6 to 1.0 in both the years, recording highest values with 16 November and 1 December sowings irrigated at 1.0 ratio during 1994–95 and 1995–96 respectively. Latest sowings irrigated at 0.6 ratio had lowest crop water-use efficiency. Early sowings even when irrigated at 0.6 ratio recorded higher crop water-use efficiency than late sowings of January with 1.0 IW : CPE ratio as observed during 1995–96. In 1994–95 also, 1 November sowing with all 3 irrigation schedules had higher crop water-use efficiency than the corresponding irrigation schedules of late sowings of January. The results indicate the dominance of weather over irrigation schedules on pod yield of groundnut. The sub-optimal weather conditions during crop period with January sowing could not be mitigated by an optimum irrigation schedule.

It is evident that groundnut productivity during the winter is primarily dictated by diurnal variation in temperature and minimum temperature during pod-filling phase. Changes in microclimate, if any due to differences in irrigation schedules could not dominate the influence of weather on groundnut productivity. The objective of sowing the winter groundnut should be such that its pod-filling phase should coincide with optimum T_{DV} and T_{min}. Since availability of irrigation water after March is limited, especially under well irrigation, there is no scope for sowing the crop beyond December. Early sowing up to 15 November may not experience optimum climatic regime during S_3 phase as such ideal time for sowing groundnut is 16 November to 16 December. If the crop is subjected to stress due to shortage of water at pod-filling phase, irrigations could be scheduled at 0.8 IW : CPE ratio with marginal decrease in pod yield.

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