

WATER ABSORPTION AND DIFFUSIVITY OF GERMINATING SEEDS OF GROUNDNUT VARIETIES AT DIFFERENT SOIL WATER POTENTIALS

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ABSTRACT

A laboratory experiment was conducted to evaluate the water absorption and diffusivity characteristics of germinating seeds of 6 varieties of groundnut (*Arachis hypogaea* L.) at different soil water potentials (0.0, -0.3 and -4.0 bar) in medium black calcareous clayey soil. The rate of water absorption was measured at the interval of 5 hr after placement of seed in soil. The water uptake at a given time and total water absorption by seeds of all varieties declined with a decrease in soil water potential. Total amount of water absorbed at the time of germination by seed of the same variety at different soil water potential varied considerably. The seeds of GG 11 and GAUG 10 absorbed the highest water at germination time. The seeds of JL 24 and GG 2 germinated at intermediate moisture content of seed and those of GAUG 1 and J 11 germinated at lower moisture content. The diffusivity of the seeds of most of the varieties decreased with increase in time. The average diffusivity value of most of the varieties decreased with decrease in soil water content.

INTRODUCTION

Good seed germination and seedling emergence has a primary role in the establishment of satisfactory crop stand. Because of the erratic precipitation and high evaporation, especially during summer, the amount of moisture in the soil is often inadequate for seed germination and seedling establishment. Hunter and Erickson (1952) observed that in order for the seed to germinate, each species of seed had to attain a specific moisture content. The value of water uptake by seed is determined by the difference in water potential between seed and germination medium and the conductivity of seed. Hadas and Russo (1974) reported that a smaller seed-water contact area reduced the rate of water uptake and thus caused delay in germination. However, little information is available on the water absorption characteristics of germinating groundnut seeds. Therefore, an attempt has been made to evaluate the water absorption and diffusivity of germinating seeds of groundnut varieties at different soil water potentials.

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MATERIAL AND METHODS

A laboratory experiment was conducted to study the water absorption characteristics of six groundnut varieties (GG 11, GAUG 10, JL 24, GG 2, GAUG 1 and J 11) and three soil water potentials (0.0, -0.3 and -4.0 bar) during 1988, using seed germinator at constant temperature viz $28.5 \pm 1^\circ\text{C}$ and 70 per cent humidity with two replicates. The value of 0.0, -0.3 and -4.0 bar correspond to the water potential of free water, water potential at field capacity and the water potential when most of the available water had been released by the soil. The soil used was medium black calcareous clayey, sieved through 2 mm screen. It had pH 7.8, clay 62.6%, CEC 56.1 meq/100 g and hydraulic conductivity 6.5 mm/hr. The soil moisture at 0.0, -0.3 and -15.0 bar potentials was 61, 38 and 18 per cent, respectively.

A measured quantity of soil was kept in each aluminium box (7.6 cm diameter and 3.9 cm height). Ten weighed healthy uniform sized seeds were selected for each variety and placed at a depth of 2 cm in each box. The desired soil water potentials (0.0, -0.3 and -4.0 bar) were obtained by adding calculated amount of water in each box and all boxes were kept in seed germinator. At differing interval of 4, 8, 12, 16, 20, 24, 28, 32 and 36 hr after, seeds were placed in soils, the seeds were removed from the soil, quickly cleaned, blotted on a cotton towel to remove soil and weighed. These seeds were then discarded. A new set of experiment was used to measure water absorption at each interval of time. The water absorption by seed at various time intervals was expressed as percentage on air dry basis. A seed was considered to have germinated when the radicle was 2 to 4 mm long.

The diffusivity of germinating seed can be calculated if certain conditions are fulfilled. These conditions are: (1) the ratio of amount of water absorbed at a given time to amount of water absorbed at the time of germination must exceed a certain critical value for the ratio of the time required for germination to the time under consideration, and (2) the shape of the seed is assumed to be a sphere but the seed can deviate considerably from the shape of a sphere, for example, football shaped, without introducing appreciable error.

The flow equation for spherical geometry with water moving only in the radial direction is:

$$\partial\theta/\partial t = (D/r) \partial^2 (r \theta)/r^2 \dots\dots (1)$$

Where θ is the moisture content, volume basis, of the seed; D is the diffusivity which is assumed to be constant, t is the time, and r is the radial distance from the centre of the seed. The detailed assumptions, initial and boundary conditions as well as solution of equation (1) are reported elsewhere (Phillips 1968) and the final equation as reported is given below:

$$\frac{M(t)}{M(tg)} = \frac{\sum_{m=1}^{\infty} \frac{\pi^2}{6} (1/m)^2 \exp(-Dm^2 \pi^2 t/a^2)}{\sum_{m=1}^{\infty} \frac{\pi^2}{6} (1/m)^2 \exp(-Dm^2 \pi^2 tg/a^2)} \dots\dots\dots(2)$$

Where M (t)/M(tg) is the ratio of the total amount of water , M (t), taken up by the seed at the time, t, to the amount of water taken up at the time of germination M (tg). The diffusion coefficient D cannot be explicitly evaluated from equation (2). D values can be evaluated by a graphical procedure if M(t)/M(tg) values and t, tg and 'a' (equivalent radius of seed), are known experimentally. A plot of M(t)/M(tg) as a function of $\frac{(D t)}{\pi a^2}$ is shown in Fig. 2 for several ratios of tg/t. Diffusivity

values, D, can be calculated from the data shown in Fig 2. if the experimental values M(t)/M(tg), tg/t and 'a' are known.

RESULTS AND DISCUSSION

Water absorption

For a given time, the amount of water absorbed declined with the decrease in soil water potential (Swp). The total water uptake also increased with a corresponding lowering of water potential (Fig. 1). Seeds of groundnut varieties germinating at 0.0 bar SWP absorbed the maximum amount of water and that too with higher rate of absorption. The influence of SWP on potential differences between seed and soil becomes increasingly important with each increment of water absorbed. More water absorption by the seeds at 0.0 bar SWP confirms the results of Hadas and Stibbe (1973), who reported that a seed will take up water as long as its water potential is lower than the external water potential at its surface.

The seeds of GG-11 and GAUG 10 absorbed more water and their germination occurred at higher moisture content of seed at all the three SWP compared with other varieties. This indicates that the seeds of these varieties have higher optima for water required for germination. The seed of JL-24 and GG-2 germinated at intermediate moisture content and those of GAUG-1 and J-11 germinated at lower moisture content at all three SWP. Thus all the varieties of groundnut studied, did not require same amount of water for germination judged from both initial and final percentage of water content. These results are in conformity with the finding of Patel and Patel (1986) who observed that several varieties of groundnut did not require same amount of water for germination. Similar results were also reported by Mali et al. (1979) in case of sorghum cultivars. We also found that the germinating seeds of all the varieties of groundnut absorbed more water at 0.0 bar SWP confirms the results of Hadas and Stibbe (1973), who reported that a seed will take up water as long as its water potential remains lower than that of the external water potential at its surface.

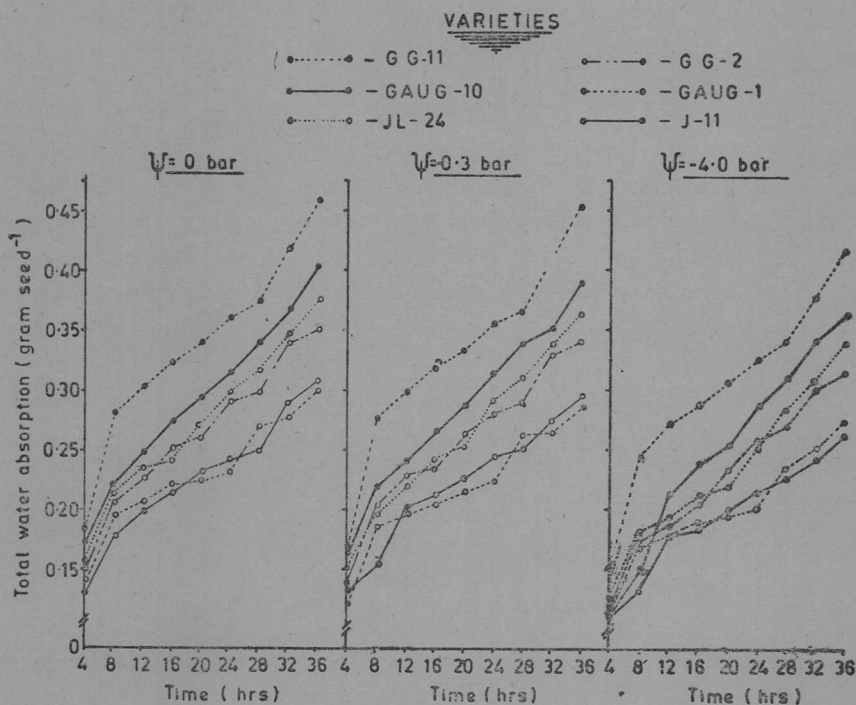


FIG.1. WATER ABSORPTION BY GERMINATING GROUNDNUT SEEDS AS A FUNCTION OF TIME AND SOIL-WATER POTENTIAL. Ψ = SOIL-WATER POTENTIAL

The total amount of water taken up at the time of germination by seed of the same varieties at the three different SWP varied considerably (Table 1 and Fig. 3). The seeds of GG-11 absorbed 0.363 and 0.400 g seed⁻¹ water at time of germination in -4.0 and -0.3 bars, respectively, whereas they required 0.415 g seed⁻¹ water for germination at 0.0 bar SWP. This indicates the adaption of seed to germination modification in xeric, mesic and hydric habits, as reported by Stiles (1949). More water was absorbed by the seeds of GG-11 and GAUG-10 owing to bigger size seeds and large storage materials which facilitate larger area of seed-water contact and thereby increased the rate of water uptake. The smaller size seeds of GAUG-1 and J-11 required less quantity of water for germination owing to less storage material and lower area of seed-water contact. Such results are also reported by Hadas and Russo (1974) and Mali et al. (1979). Thus, seeds of GAUG-1 and J-11 seem to exhibit adaption to germination in drylands, which was indicated by their low optima water requirement for germination (Table 1). This assumption is based on the fact that seeds in xeric habits have low water requirement for germination (Stiles 1949). The seeds of GG-2 and JL-24 seem to be better adjusted to germinate in moderate soil-water potential, because of their intermediate water requirement for germination. The seeds of varieties GG-11 and GAUG-10 required higher amount of

Table 1. Moisture absorption and dimensional statistics of seeds of six varieties of groundnut (average of five seeds)

Variety	Volume of air dry seed (cm ³)	Major axes (cm)	Minor axes (cm)	Sphere equivalent radii 'a' (cm)	Amount of water absorption at germination time (tg.). (gram/seed)		
					0 bar	-0.3 bar	-4.0 bar
GG 11	0.90	1.70	0.88	0.65	0.415	0.400	0.363
GAUG 10	0.75	1.49	0.81	0.66	0.335	0.321	0.299
JL 24	0.65	1.46	0.68	0.58	0.325	0.315	0.300
GG 2	0.50	1.18	0.90	0.55	0.282	0.278	0.249
GAUG 1	0.40	1.08	0.66	0.50	0.274	0.266	0.232
J 11	0.50	1.03	0.67	0.52	0.264	0.255	0.229

water for germination and therefore might be adjusted to germinate in a hydric habit.

The decrease in water potential from 0.0 to -0.3 bars brought about a narrow difference in the amount of water absorbed at the time of germination, but subsequent decrease in SWP to -4.0 bar decreased the water absorption considerably, though all seeds germinated at the same time (32 ± 4 hr). According to the Hadas and Stibbe (1973), once a seed attains a critical value of hydration, it will proceed towards germination. It appears that different varieties absorbed water preferentially as a function of time and soil water potential probably due to its physical and physiological nature.

Seed water diffusivity

The average sphere equivalent radii of germinating seeds of groundnut varieties and total amount of water required for germination M (tg) are shown in Table 1.

An example of calculating seed water diffusivity (D) from the data given in Table 1 and Fig. 2 is as follow : (a) select value of (tg/t) from Fig. 2 say for JL-24 at 0.0 bar SWP, tg/t = 2.5, (b) calculate t, t = 12 hr. since tg = 30 hr. (c) from Fig. 3 read off the value of M(t)/M(tg) = 0.71 for t = 12 hr, (d) from Fig. 2 find the value of $D \cdot \frac{\pi^2}{a^2} t = 0.31$ corresponding to M(t)/M(tg) = 0.71 and tg/t = 2.5 and (e) calculate

D from the value found in step (d); in our example $D = 0.88 \times 10^{-3} \text{ cm}^2 \text{ hr}^{-1}$, where $\pi^2 = 9.8696$, $a^2 = 0.3364 \text{ cm}^2$ and t = 12 hr. The D value of six varieties of groundnut germinating in medium black calcareous clay soil under varying SWP were calculated for several values of time, t, as outlined by foregoing procedure. (Table 2).

The D value for each variety of seed differed considerably during germination at different SWP (Table 2). The D values of all the varieties of groundnut under varying SWP with some exception, decreased with increasing time. The average D

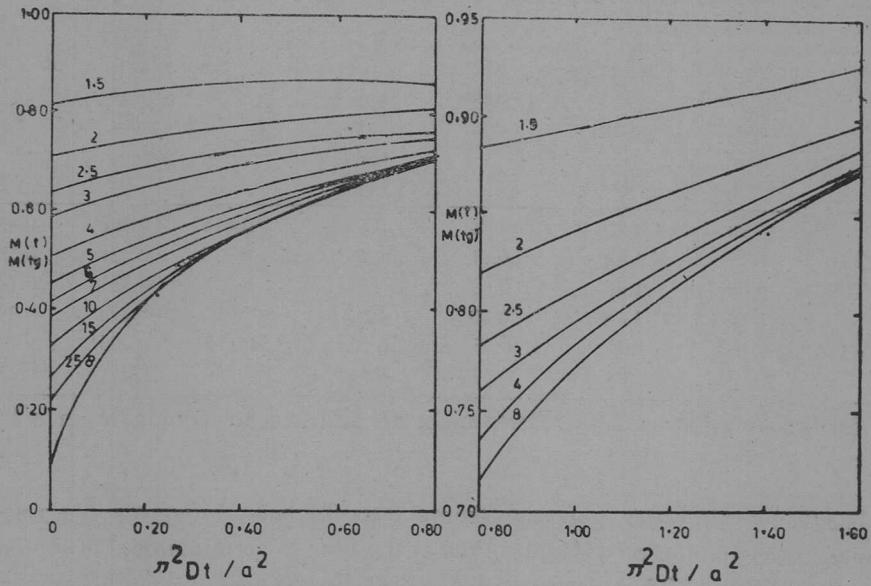


FIG. 2. $M(t) / M(tg)$ FROM EQUATION (2) PLOTTED AS A FUCTION OF $\pi^2 Dt/a^2$. THE VALUES ON THE CURVES ARE tg / t RATIOS WHERE tg : TIME REQUIRED FOR GERMINATION and t : TIME

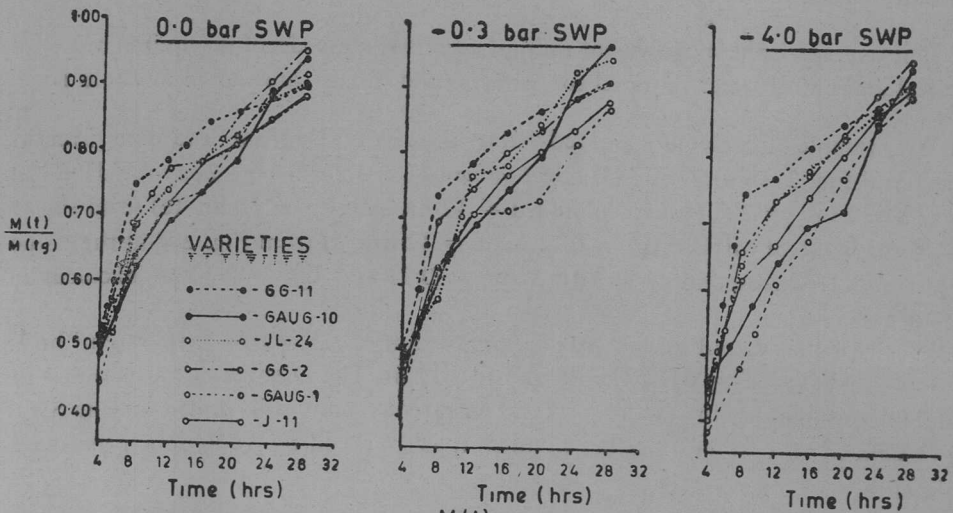


FIG. 3. ABSORPTION OF WATER $\frac{M(t)}{M(tg)}$ BY SEEDS OF GROUNDNUT VARIETIES AT VARYING SOIL WATER POTENTIALS AS A FUCTION OF TIME

Table 2. Diffusivity to water of groundnut varieties in medium black calcareous soil at varying soil water potentials.

Soil water potential (bar)	Variety										
	JL-24					GG-2					
	Time for germination 'tg' (hr)	Time after placing in soil 't' (hr)	tg/t	M(t)/M(tg)	$D \times 10^{-3}$ cm ² hr ⁻¹	Time for germination 'tg' (hr)	Time after placing in soil 't' (hr)	tg/t	M(t)/M(tg)	$D \times 10^{-3}$ cm ² hr ⁻¹	
1	2	3	4	5	6	7	8	9	10	11	
0.0	30	4.3	7	0.43	0.64	30	4.3	7	0.49	1.43	
		5.0	6	0.48	0.74		5.0	6	0.55	1.72	
		6.0	5	0.55	1.36		6.0	5	0.60	2.15	
		7.5	4	0.59	1.14		7.5	4	0.73	2.09	
		10.0	3	0.67	0.99		10.0	3	0.73	2.09	
		12.0	2.5	0.71	0.88		12.0	2.5	0.76	1.97	
		15.0	2	0.72	0.05		15.0	2	0.78	1.02	
		20.0	1.5	0.82	*		20.0	1.5	0.85	0.29	
-0.3	30	4.3	7	0.43	0.64	30	4.3	7	0.49	1.43	
		5.0	6	0.47	0.75		5.0	6	0.52	1.47	
		6.0	5	0.56	0.53		6.0	5	0.53	0.92	
		7.5	4	0.56	0.64		7.5	4	0.56	0.57	
		10.0	3	0.66	0.85		10.0	3	0.67	0.89	
		12.0	2.5	0.71	0.88		12.0	2.5	0.76	1.97	
		15.0	2	0.71	*		15.0	2	0.77	0.88	
		20.0	1.5	0.72	*		20.0	1.5	0.84	0.15	
-4.0	32	4.6	7	0.37	*	32	4.6	7	0.45	0.81	
		5.3	6	0.49	*		5.3	6	0.49	0.98	
		6.4	5	0.42	*		6.4	5	0.54	1.06	
		8.0	4	0.48	*		8.0	4	0.64	1.65	
		10.7	3	0.54	*		10.7	3	0.69	1.18	
		12.8	2.5	0.62	*		12.8	2.5	0.74	1.42	
		16.0	2	0.67	*		16.0	2	0.77	0.84	
		21.3	1.5	0.79	*		21.3	1.5	0.82	0.04	

Contd.

1	J 11					GAUG 1					
	2	3	4	5	6	7	8	9	10	11	
0.0	28	4.00	7	0.49	1.44	30	4.29	7	0.48	1.02	
		4.67	6	0.52	1.35		5.00	6	0.52	1.07	
		5.60	5	0.56	1.64		6.00	5	0.56	1.22	
		7.00	4	0.67	2.19		7.50	4	0.62	1.14	
		9.33	3	0.75	2.29		10.00	3	0.67	0.73	
		11.20	2.5	0.77	*		12.00	2.5	0.71	0.65	
		14.00	2	0.80	1.49		15.00	2	0.75	0.32	
		18.67	1.5	0.85	0.28		20.00	1.5	0.80	—	
-0.3	28	4.00	7	0.48	0.96	30	4.29	7	0.46	0.29	
		4.67	6	0.50	2.70		5.00	6	0.50	0.92	
		5.60	5	0.55	1.27		6.00	5	0.55	1.01	
		7.00	4	0.67	2.15		7.50	4	0.60	0.91	
		9.33	3	0.75	2.29		10.00	3	0.66	0.61	
		11.20	2.5	0.77	*		12.00	2.5	0.70	0.53	
		14.00	2	0.80	1.49		15.00	2	0.74	0.23	
		18.67	1.5	0.85	0.28		20.00	1.5	0.80	*	
-4.0	30	4.29	7	0.44	0.64	32	4.57	7	0.44	0.53	
		5.00	6	0.51	1.09		5.33	6	0.46	0.41	
		6.00	5	0.59	1.96		6.40	5	0.51	0.42	
		7.50	4	0.67	2.01		8.00	4	0.61	0.97	
		10.00	3	0.75	2.13		10.67	3	0.64	0.39	
		12.00	2.5	0.76	1.66		12.80	2.5	0.68	0.32	
		15.00	2	0.81	*		16.00	2	0.74	0.21	
		20.00	1.5	0.85	0.23		21.33	1.5	0.82	0.03	

Contd.

GAUG 10										
GG 11										
1	2	3	4	5	6	7	8	9	10	11
-0.0	30	4.57	7	0.43	0.77	32	4.57	7	0.47	1.36
		5.33	6	0.48	1.08		5.33	6	0.50	1.39
		6.40	5	0.55	1.80		6.40	5	0.53	0.97
		8.00	4	0.68	3.20		8.00	4	0.61	1.56
		10.67	3	0.71	2.19		10.67	3	0.65	0.77
		12.80	2.5	0.74	2.04		12.80	2.5	0.68	0.55
		16.00	2	0.78	1.30		16.00	2	0.73	0.17
		21.38	1.5	0.82	0.06		21.33	1.5	0.80	*
-0.3	32	4.57	7	0.45	1.16	32	4.57	7	0.48	1.53
		5.33	6	0.50	1.58		5.33	6	0.51	1.46
		6.40	5	0.58	2.49		6.40	5	0.54	1.28
		8.00	4	0.69	3.53		8.00	4	0.61	1.61
		10.67	3	0.72	2.53		10.67	3	0.65	0.77
		12.80	2.5	0.75	2.28		12.80	2.5	0.69	0.64
		16.00	2	0.80	2.07		16.00	2	0.74	0.34
		21.33	1.5	0.84	0.23		21.33	1.5	0.81	*
-4.0	36	5.14	7	0.43	0.69	36	5.14	7	0.48	1.36
		6.00	6	0.51	1.47		6.00	6	0.49	0.97
		7.20	5	0.57	1.96		7.20	5	0.51	0.65
		9.00	4	0.67	2.70		9.00	4	0.58	0.87
		12.00	3	0.73	2.36		12.00	3	0.64	0.55
		14.40	2.5	0.75	2.03		14.40	2.5	0.67	0.32
		18.00	2	0.80	0.80		18.00	2	0.70	*
		24.00	1.5	0.87	1.47		24.00	1.5	0.72	*

*Indicates diffusivity value which could not be calculated from Fig. 2

value of GG-2, GG 11 and J 11 was almost same ($1.5 \times 10^{-3} \text{ cm}^2 \text{ hr}^{-1}$) which was approximately 2 times larger than those of JL 24, GAUG 1 and GAUG 10 under 0.0 bar SWP. However, the average D value of GG 11 ($1.98 \times 10^{-3} \text{ cm}^2 \text{ hr}^{-1}$) was same under -0.3 and -4.0 bar SWP and which was approximately 5, 3, 2 and 1.5 times larger than those of GAUG 1, GAUG 10, GG 2 and J 11 under -4.0 SWP. It is interesting observation that the average D value was higher in GG 11 as compared to other varieties at any SWP. It is apparent from data that the D values of germinating seeds were very low beyond 15.0 hours after placing the seeds in soil. Similar observations reported earlier in corn, cotton, gram, cowpea and soybean were described due to adaption induced by metabolic changes occurring within the seeds resulting from the seeds storage materials and genetic properties (Hadas and Stibbe, 1973; Chatterjee et al. 1981, 1982). It was concluded that at a given low SWP, the seeds of GG 11 may germinate whereas those of GAUG 10 may germinate late or even fail to germinate owing to their higher optima water requirement for germination and emergence. It appears that it is possible to avoid the risk of germination in drylands where water is not uniformly available.

The smaller size seeds of GAUG 1 and J 11 which have lower optimum water requirement for germination coupled with low seed water diffusivity under low soil water potential could germinate very well under the conditions of fluctuating available soil water content in dryland areas giving rise to better plant stand establishment.

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