Indian Journal of Agricultural Sciences **74** (11) : 588–93, November 2004

Influence of drying method and temperature on germinability and vigour of groundnut (*Arachis hypogaea*) seed harvested in summer season

PRAKASH C NAUTIYAL[1] and PRATAP V ZALA[2]

National Research Centre for Groundnut, Junagadh, Gujarat 362 001

Received: 11 November 2003

ABSTRACT

A study was conducted with 'GG 2' groundnut (*Arachis hypogaea* L.) during the 1998 and 1999 at the National Research Centre for Groundnut, Junagadh, to assess the effect of pod drying temperatures on the crop harvested in summer (May–June) season, both under laboratory controlled conditions and natural conditions in the field. Pods immediately after harvest were dried at one of the temperatures, ie 39°C, 50°C, 60°C and 70°C, under controlled conditions, whereas pods were dried by 10 different drying methods under natural field conditions. Drying of pods at high temperatures either in the laboratory or field conditions adversely affected germination immediately after drying, for example, drying of pods at 39% moisture and 60°C temperature showed 92% and 74% germination respectively. Pods dried under natural field conditions in windrows experienced mean temperatures about 45°C and showed 74% germination. Pods dried by windrows and conventional farmer's methods lost about 50% germination, after 3 months of storage. However, pods dried by the National Research Centre for Groundnut (NRCG) method, which protected the pods from the direct exposure of sun rays by the haulm of the plant in a tripod type of structure, retained >80% germination, even after 9 months of storage. Further this method also helped in maintaining the seedling vigour, and seed-coat colouration, when pod experienced rain during drying under the field conditions.

Keywords: Groundnut, *Arachis hypogaea*, Pod drying methods, High temperature effects, Germinability, Summer season

In India, rapid loss of germinability is a serious problem in groundnut (*Arachis hypogaea* L.) harvested in summer season, because about 50% germination could be lost within 4–5 months of storage in such seed due to exposure of pods to high temperature, while drying in the field (Nautiyal *et al.* 1990, Nautiyal and Joshi 1991). Groundnut pod moisture content is the most critical factor in the post-harvest operations such as harvesting, curing or drying, storage, and marketing. Pods after harvest are subjected to the curing and drying processes until they achieve moisture about 6–9%, for the safe storage. During drying many physiological, chemical and physical changes occur in the pod (Sanders *et al.* 1982), however, the nature and extent of these changes are not fully understood. Seed germination was lost considerably in the seed dried following windrow and conventional farmers' methods (Nautiyal and Zala 1991, Nautiyal *et al.* 2004). Limited information is available on the effects of drying methods on germinability and changes in solute leakage, which might indicate membrane damage in groundnut (Nautiyal and Zala 1991, Nautiyal and Ravindra 1996). As detailed information on the rate of loss of moisture from the pod and effect of drying temperatures under controlled and field conditions are not available in the Indian groundnut cultivars, a study was aimed to understand the effect of drying temperatures, under controlled and field conditions on both germinability and storability of seed and to suggest a suitable method over the conventional farmers' drying methods.

MATERIALS AND METHODS

The experiment was conducted in 1998 and 1999 summer (May–June) at the National Research Centre for Groundnut, Junagadh (21°31N, 70°36 E) with 'GG 2' groundnut (*Arachis hypogaea* L. ssp *fastigiata* var *vulgaris*), which lacks fresh-seed dormancy (Nautiyal *et al.* 2001a).

Pods after thorough drying were stored in cotton bags in 3 replicates. Bags were kept inside the galvanized-bins at ambient laboratory conditions (maximum and minimum relative humidity 98% and 20%, a maximum and minimum temperatures 41°C and 21°C respectively). Bins were opened every month to monitor the storage pest, and bags were randomized again. Fumigating the storage bins with celphos controlled the pest. Immediately after drying seed were analysed for germinability and vigour tests, electrical conductivity of the seed leachate. The same measurements were repeated at 3-month intervals till 9 months storage. Three replicates of 50 seeds each were

[1]Senior Scientist, Plant Physiology, [2]Technical Officer, Plant Physiology

kept in an incubator at 30°C ± 1°C in rolled germination papers (between substrate). Germination (%) of normal seedlings was recorded on day 7 of incubation following ISTA rules (1993). Root length was measured on 15 seedlings taking randomly from each replicate. Seedling-vigour index (SVI) was calculated according to Abdul-Baki and Anderson (1973). Electrical conductivity of seed leachate was measured on conductivity bridge meter by soaking 5 seeds in 25 ml double distilled water for 18 hr at 27°C in an incubator.

Drying of pod

In trial I, immediately after harvest, approximately 1 kg pods of 'GG 2' groundnut were dried at one of the temperatures, i e 39°C, 50°C, 60° and 70°C ± 1°C in forced hot-air-flow drier in 0.09 m^2 area at an airflow rate of 2.48 m^3/min and velocity 0.46 m^2/sec. Loss of moisture from the pod during drying at 4 different temperatures was recorded by measuring the pod weight at various time intervals until they attained moisture content around 7% as:

$$W_2 = \frac{100 - M_1}{100 - M_2} \times W_1$$

where W_1, initial weight of pods; W_2, final weight of pods; M_1, initial moisture content (%); M_2, final moisture content (%). Further, the amount of water to be removed in a drying process was determined as per the formula of Young *et al.* (1982). Immediately after harvest, and after 3 months storage, seeds were analysed for germinability and electrical conductivity of the seed leachate.

In trial II, immediately after uprooting the plants, pods were dried by one of the following methods for 5 days in replicate trial. In windrows drying plants were left in single rows in flat position in direct sunlight. In shade drying plants after harvest were tied in bundles of 0.5 m diameter and kept in the open-shaded place in an inverted position, ie pods upside and shoots part downward.

In the National Research Centre for Groundnut method (NRCG method), a tri-pod type structure (pyramid shape) was raised in the field with the help of 3 bamboos poles of about 1.5 m length. A coir rope was arranged around the structure starting from the bottom to the top, while maintaining a space of 60–80 cm between 2 loops. Immediately, after harvest groundnut plants were hanged on the rope of the structure in inverted position, pods up and haulms down, and the structure was filled with groundnut plants in a way that the haulm of an upper ring covered the pods of the lower ring thus forming a sloping structure like the roofing of a thatched house. The plants were arranged bottom ring upwards (Nautiyal *et al.* 2001b).

In the Directorate of Oilseeds Research method (DOR method), plants were tied in bundles of about 0.5 m in diameter and kept for drying in pairs in such a way that 1 of the pairs was placed in the field upside down and the other on the top of the former right side up with platform between 2 bundles (DOR 1983).

The farmers' conventional method followed in Saurastra region of Gujarat was followed to dry pods. In this method, about 40–50 plants were randomly heaped, majority of the pods in the upper part of heap got exposed to direct sunlight. In ring method plants were arranged in a ring of about 1.5 m diameter and 0.5 m height with pod facing the centre of the ring. For pods in different directions during drying, plants were arranged in small heaps of about 0.8 m length and 8 to 10 layers of plants in height (0.5 m) with pods facing 4 different directions, i e East, West, South and North, in the field.

In 1998 however, the crop was dried in 2 sets. The first was set up on 1 June 1998 and all the above-mentioned methods were followed. A second set was arranged on 6 June 1998, where pods were dried only following the windrows, conventional, NRCG and DOR methods, and the performance of these methods in the situations when drying encounters rains was compared. The second set experienced rains on day 4 and 5 (16 mm) of curing in the field.

Measurement during curing

Pod surface and surrounding temperatures were measured with a thermocouple sensor, and infrared thermometer (Thermo-Hunter 5140), respectively, between 9 and 18 hr at 3-hr interval. Pod moisture content was assessed in triplicate samples; approximately 10 g were hand picked from each replicate immediately after harvest and each morning at 9 hr thereafter. Pod moisture was calculated gravimetrically in an oven at 80°C till the constant weight, and expressed on wet weight basis (W/B). After drying for 5 days pods were stripped manually and dried in thin layer. At the time of storage, the moisture content was between 5% and 6% in set I, and 6.5% and 8% in set II in 1988 and 9% and 10% in 1999.

During drying in the set I in 1998 weather was quite dry and hot, as the temperature and ambient relative humidity (%) during the day time was between 27° and 39°C, and 54% and 85% respectively. Average pan evaporation and wind velocity were 10 mm/day and 13.0 km/hr, with high sunshine hr (9 to 10). While in set II pods during curing experienced rain, resulting higher relative humidity (between 63% and 90%). On the other hand, during 1999 drying period weather was humid (average humidity 92%) with low sunshine hr (0 to 5) and an average wind velocity of 10.5 km/hr.

RESULTS AND DISCUSSION

Effect of temperature on drying of pods under controlled conditions

As loss of moisture from pods dried at different temperatures, and thereafter seed germination percentage followed similar trend in the respective temperature during 2 summer seasons (Table 1). At harvest, pod contain about 48%–50% moisture and lost at a faster rate in drying at 50°C, 60°C and 70°C compared to 39°C, when ambient temperature was around 38°C. Pod during the initial drying lost moisture rapidly, for example, in the half-an-hour about 23% and 10% moisture was lost at 70°C and 39°C respectively. Thus drying of pod up to 7% moisture level at which seed is stored, took about 29 hr at 39°C, 18 hr at 50°C, 13 hr at 60°C and 7.5 hr at 70°C. Seed germination and electrical conductivity differed due to drying temperatures, being 92% both in seed dried at 39°C and 50°C, and 74% in seed dried at 60°C and 70°C, immediately after drying. Irrespective of the drying temperatures, germinability declined sharply after 3 months storage, being highest (64%) in seed dried at 39°C. Electrical conductivity of the seed leachate also increased with increase in drying temperature, and storage period (Table1). It is also possible that rapid loss of germinability of the seed dried at higher temperatures such as 50°C, 60°C and 70°C, may be due to the lower rate of respiration during curing causing cell damage (Schenk 1961).

Sanders (1973) found progressive inhibition of lipase with time during curing at 50°C. Thus during pod drying process the equilibrium moisture content is very important consideration, as it is dependent on the moisture content of the shell and seed and is a function of the temperature and relativity of the environment to which it is exposed. In addition, the temperature may also affect the drying by changing the value of the drying parameters, which is a function of material, moisture content, and temperature, time and air velocity (Young 1977).

Table 1 Effect of different pod drying temperatures on germination percentage and electrical conductivity of the seed leachate in groundnut

Drying temperature	Storage period (months)			
	Germination (%)		EC of seed leachate [EC (μs/g)]	
	0	3	0	3
39°C	92	64	0.052	0.067
50°C	92	21	0.057	0.200
60°C	74	15	0.087	0.227
70°C	73	12	0.100	0.255
LSD (P = 0.05)		6.65	0.034	

EC, Electrical conductivity

Effect of temperature on drying of pod under natural conditions

Among all the drying methods, maximum loss of moisture from pods was recorded on day 3; however, the rate of loss of moisture was highest in windrows and lowest in the National Research Centre for Groundnut method (Fig 1). After thin layer drying pod could attain a safe moisture level between 5% and 6.5% in 1988 and 8.7% and 9.5% in 1999. Variation in the pod moisture during the 2 different years was mainly due to the variations in the prevailing weather conditions during the drying period. Thus the high pod moisture in 1999 season and in set II in 1998, at the time of storage adversely affected the germinability (Tables 2, 4). Pod temperatures varied in various drying methods during daytime (Fig 2). The difference in the temperatures of the pod surface and surroundings was highest in windrows (Fig 2a). In the National Research Centre for Groundnut method, also the difference between the pod surface, and surrounding temperature was less by 2–3°C (Fig 2c). In the Directorate of Oilseeds Research method, pod temperature varied among the pod located in the periphery and central part of the pair of bundles by 1–3°C (Fig 2 d). In conventional method, pod exposed to direct sunlight experienced temperature up to 41°C during afternoon hours (Fig 2 f). Thus the seed dried following various methods showed different rate of loss of moisture due to variation in the drying temperatures, intern influenced the germinability, seedling vigour and electrical conductivity, both immediately after drying and during storage. For example, in windrows, ring, and conventional methods most of the pods were exposed

Table 2 Effect of drying methods on germination (%) and seedling vigour index, immediately after drying (0 month) and during storage in 2 summer seasons

Drying method	Germination (%) and SVI at storage period (months)							
	1998				1999			
	0	3	6	9	0	3	6	9
DOR method	92 (727)	90 (693)	66 (495)	57(361)	96 (985)	82 (691)	52 (289)	38 (173)
NRCG method	98 (846)	94 (647)	85 (547)	83 (355)	95 (927)	88 (668)	60 (173)	48 (104)
Windrows drying	74 (1 009)	50 (939)	25 (779)	18 (643)	75 (1037)	62 (795)	16 (354)	8 (251)
Farmers' method	94 (574)	80 (360)	66 (163)	59 (72)	96 (628)	83 (436)	49 (47)	35 (21)
Shade drying	96 (930)	90 (869)	86 (699)	83 (638)	90 (932)	84 (608)	59 (341)	47 (236)
Ring drying	88 (865)	83 (737)	70 (523)	56 (416)	88 (882)	79 (614)	39 (255)	30 (130)
Pods in East	85 (740)	78 (622)	62 (454)	54 (332)	86 (900)	74 (547)	45 (197)	33 (134)
Pods in West	88 (680)	87 (640)	66 (474)	65(422)	89 (878)	79 (616)	55 (294)	25 (96)
Pods in North	86 (711)	84 (663)	74 (529)	64 (438)	94 (1002)	79 (635)	46 (247)	32 (113)
Pods in South	92 (722)	86 (642)	78 (564)	73 (487)	90 (930)	78 (603)	58 (311)	40 (203)
LSD (P = 0.05)		7.87 (117.44)		8.97 (96.61)				

DOR method, Directorate of Oilseeds Research method; NRCG method, National Research Centre for Groundnut method
Figures in parentheses indicate values of seedling vigour index

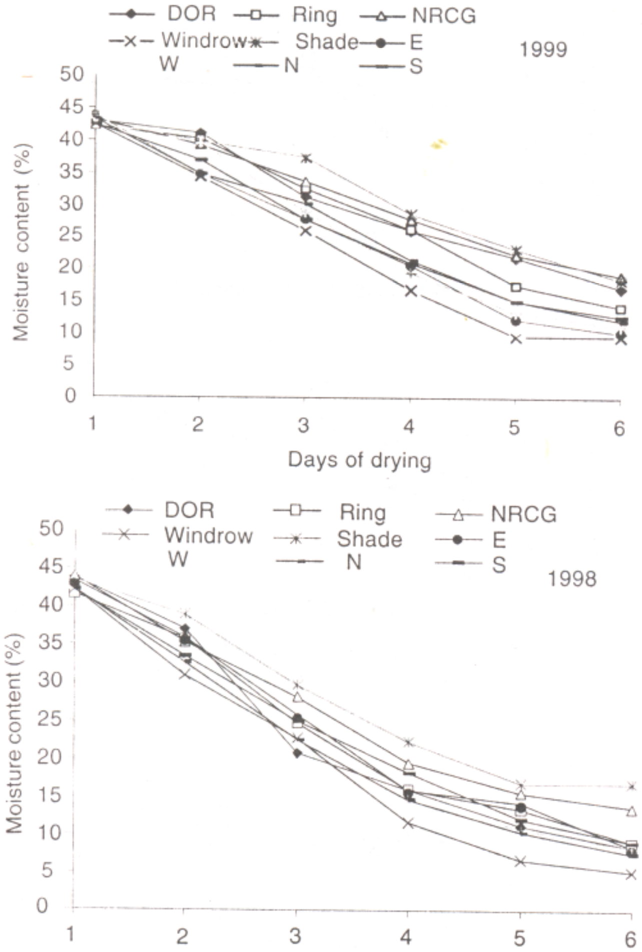

Fig 1 Loss of moisture from pods dried by various methods under field conditions [LSD ($P = 0.05$) for 1998 : drying method × days of drying (2.32), and for 1999 : drying method × days of drying 1.98]. DOR, Directorate of Oilseeds Research; NRCG, National Research Centre for Groundnut; E, East; W, west; N, north; S, south

Table 4 Effect of 4 different drying methods and rain under field conditions on germinability, seedling vigour index and electrical conductivity of seed leachate (EC) in groundnut

Drying method	Storage period (months)					
	Germination (%)		SVI		EC (µs/g)	
	0	9	0	9	0	9
Summer 1998 (set I)						
DOR method	93	66	863	450	0.032	0.099
NRCG method	98	82	1101	548	0.031	0.070
Windrows drying	74	18	574	74	0.073	0.171
Farmers' method	94	59	865	416	0.038	0.108
LSD ($P = 0.05$)	9.16	112.72	0.014			
Summer 1998 (set II)						
DOR-method	92	49	728	271	0.052	0.107
NRCG method	91	81	936	686	0.031	0.085
Windrows drying	69	22	568	72	0.039	0.113
Farmers' method	90	40	860	405	0.037	0.118
LSD ($P = 0.05$)	11.81		127.32		0.020	

DOR method, Directorate of Oilseeds Research method; NRCG, National Research Centre for Groundnut method

to the direct sunlight, which has increased the pod surface temperatures. Even the pod facing the different direction during drying also influenced germinability, being highest in seed dried facing South direction (Table 2).

Among the drying methods, electrical conductivity of the seed leachate was highest in windrows (0.171 µs/g in 1998 and 0.318 µs/g in 1999), followed by pod in East direction (0.113 µs/g in 1988 and 0.206 µs/g in 1999), after 9 months storage (Table 3). Pod drying temperatures had a great role in determining the rate of loss of moisture, which in turn affected the seed-membrane integrity, as reflected in terms of electrical

Table 3 Effect of various drying methods on electrical conductivity of seed leachate, immediately after drying (0 month) and during storage in 2 summer seasons

Drying method	EC of seed leachate (µs/g) at storage period (months)							
	1998				1999			
	0	3	6	9	0	3	6	9
DOR method	0.037	0.067	0.091	0.110	0.043	0.081	0.144	0.177
NRCG method	0.030	0.040	0.062	0.076	0.039	0.079	0.123	0.178
Windrows drying	0.073	0.078	0.120	0.171	0.114	0.121	0.127	0.318
Farmers' method	0.038	0.075	0.098	0.108	0.072	0.103	0.175	0.206
Shade drying	0.038	0.052	0.076	0.081	0.041	0.083	0.168	0.193
Ring drying	0.034	0.074	0.098	0.111	0.052	0.110	0.152	0.191
Pods in East	0.047	0.097	0.108	0.113	0.054	0.133	0.193	0.203
Pods in West	0.063	0.060	0.090	0.104	0.060	0.133	0.148	0.258
Pods in North	0.041	0.076	0.096	0.105	0.059	0.134	0.191	0.223
Pods in South	0.053	0.086	0.096	0.101	0.058	0.112	0.126	0.181
LSD ($P = 0.05$)	0.017					0.045		

DOR method, Directorate of Oilseeds Research method; NRCG, National Research Centre for Groundnut method
EC, Electrical conductivity

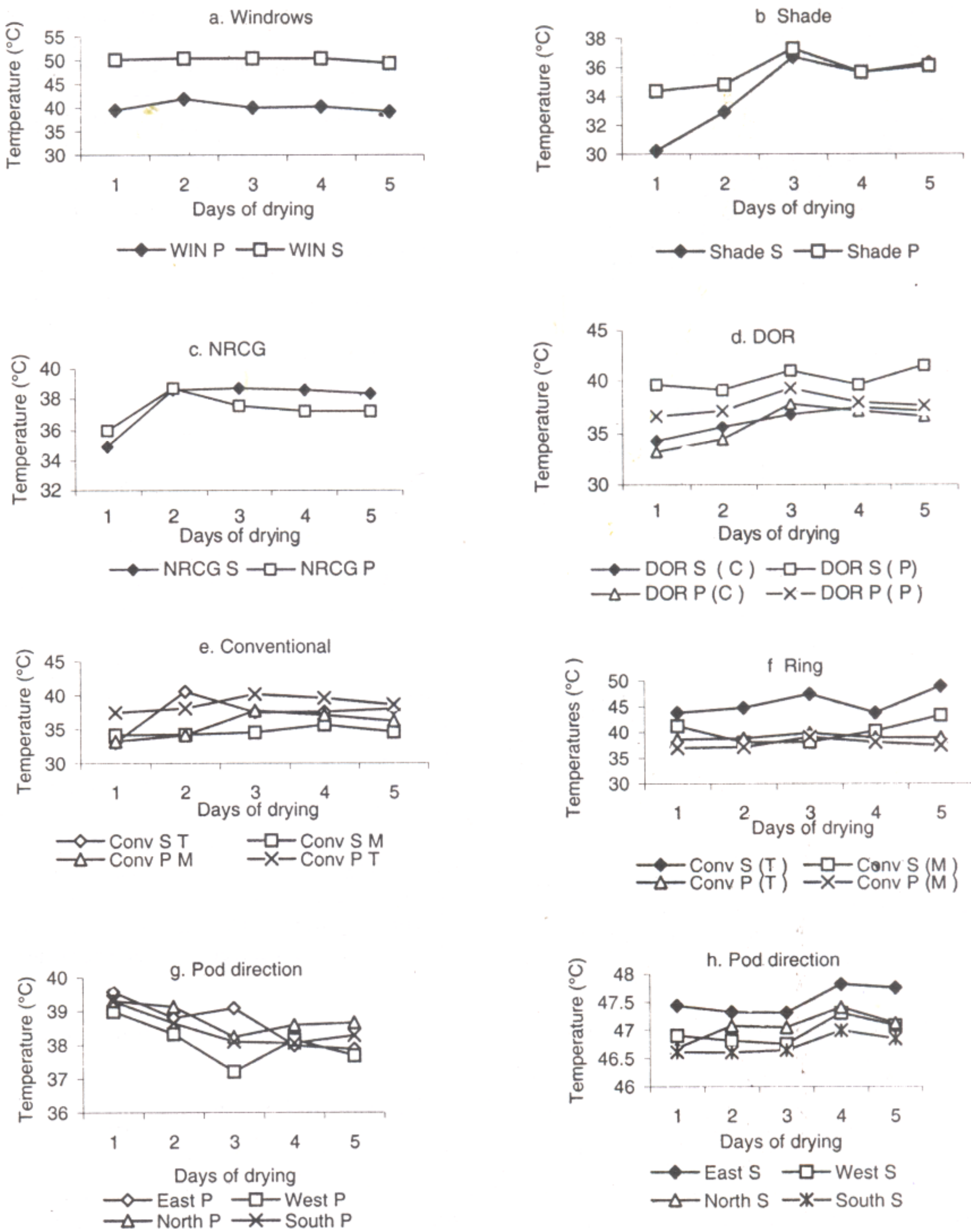

Fig 2 Pod surrounding and surface temperatures during drying in various methods under field conditions. WIN P, Pod temperatures (PT) in windrows drying; WIN S, surrounding temperatures (ST) in windrows; Shade S, ST under shade; Shade P, PT in shade drying; NRCG S, ST in NRCG method; NRCG P, PT in NRCG method; DOR (C), ST in DOR method in the central region of the bundles; DOR S (P), ST in DPR method in the peripheral region of the bundles; DOR P (C), PT in DOR method in the central region of the bundle; DOR P (P), in the DOR method in the peripheral region; Conv S T, ST in the conventional farmers' method in the top zone; Conv S M, ST in the conventional farmers' method in middle zone of the random heap; Conv P M, PT in the conventional farmers' method in the middle zone of the heap; Conv P T, PT in the conventional farmers' method in the top zone; Conv S (T), ST in the conventional ring method in the top zone; Conv S (M), ST in the conventional ring method in the middle zone; Conv P (T), PT in the conventional ring method in the top zone; Conv P (M), PT in the conventional ring method in the middle zone; East P, West P, North P, and South P, temperature of the pods dried in the East, West, North and South directions respectively; East S, West S, North S, South S, ST of the pods dried in the East, West, North and South directions respectively. LSD for drying method × days of drying (P = 0.05) for pod surrounding temperature, 0.608 and for pod surface temperature, 0.353

conductivity of the seed leachate. In groundnut Nautiyal *et al.* (1991) reported an inverse relation between electrical conductivity and germinability. In addition, high temperatures during drying may cause detachment of the seed tegument (Wright and Steele 1979) which mediates water exchange between the seed and environment (Ketring *et al.* 1976).

Better germinability, vigour and storability of seed dried by the National Research Centre for Groundnut method seem to be mainly owing to the exposure of pods at relatively lower temperatures and thus maintaining optimum rate of loss of moisture during drying. In conclusion, it is suggested that groundnut seed should not be exposed to temperatures >39°C during drying. Farmers may adopt the National Reaserch Centre for Groundnut method for drying of pods, in the summer season, to be used for the seed purpose.

REFERENCES

Abdul-Baki A A and Anderson J D. 1973. Relationship between decarboxylation of glutamic acid and vigour in soybean seed. *Crop Science* **13** : 222–6.

DOR, Hyderabad. 1983. Simple and efficient post-harvest technique for increasing seed viability of the rabi/summer groundnut. *Directorate of Oilseeds Research Newsletter* **2** : 1–5.

ISTA, Geneva. 1993. International rules for seed testing. *Seed Science and Technology* **13** : 322–441.

Ketring D L, Benedict C R and Yeger M. 1976. Growing season and location effects on water uptake and drying rates of peanut seeds from genotypes resistant and susceptible to invasion by *Aspergillus flavus*. *Agronomy Journal* **68** : 661–5.

Nautiyal P C, Ravindra V and Joshi Y C. 1990. Varietal and seasonal variation in seed viability in spanish groundnut (*Arachis hypogaea*). *Indian Journal of Agricultural Science* **60** : 143–5.

Nautiyal P C, Ravindra V and Joshi Y C. 1991. Moisture stress and subsequent seed viability: Physiological and biochemical basis for viability differences in spanish groundnut in response to soil moisture stress. *Oleagineux* **46** : 153–8.

Nautiyal P C and Zala P V. 1991. Effect of drying methods on seed viability and seedling vigour in Spanish groundnut. *Seed Science and Technology* **19** : 451–9.

Nautiyal P C and Joshi Y C. 1991. Storage of rabi/summer groundnut (*Arachis hypogaea* L.) with calcium chloride for prolonged seed viability and vigour. *Tropical Science* **31** : 21–6.

Nautiyal P C and Ravindra V. 1996. Drying and storage method to prolong seed viability and seedling vigour of rabi-summer-produced groundnut. *Journal of Agronomy and Crop Science* **177** : 123–8.

Nautiyal P C, Bandyopadhyay A and Zala P V. 2001a. *In situ* sprouting and regulation of fresh seed dormancy in Spanish type groundnut (*Arachis hypogaea* L.). *Field Crop Research* **70** : 233–41.

Nautiyal P C, Ravindra V and Zala P V. 2001b. A new method for drying groundnut pods for better seed storability. *International Arachis Newsletter* **21** : 26–30.

Nautiyal P C, Bandyopadhyay A and Misra R C. 2004. Drying and storage methods to prolong seed viability of summer groundnut (*Arachis hypogaea* L.) in Orissa. *Indian Journal of Agricultural Sciences* **74**(6) : 316–20.

Sanders T H. 1973. 'Peanut alkaline lipase, isolation, characterization and effect of high temperature curing'. Ph D thesis, Department of Botany, North Carolina University, Raleigh (*in*) *Peanut Science and Technology,* 653 pp. Pattee and Young (eds). American Peanut Research and Education Society, Yoakum, Inc. Texas, USA.

Sanders T H, Scheburt A M, and Pattee H. 1982. Maturity methodology and postharvest physiology. (*in*) *Peanut Science and Technology*, pp 624–54. Pattee anf Young (eds) American Peanut Research and Education Society, Yoakum, Inc. Texas, USA.

Schenk R U. 1961. Respiration of the curing peanut fruit. *Crop Science* **1** : 162–5.

Steele J L and Wright F S. 1977. Computer simulation of peanut drying in the windrow. ASAE Paper No. 77-3535, American Society of Agriculture Engineering, St. Joseph, MI, USA.

Wright F S and Steele L J. 1979. Potentials for direct harvesting of peanuts. *Peanut Science* **6** : 37–42.

Young J H. 1977. Simulation of peanut drying in inverted windrows. II Effect of harvest methods, *Oleagineux* **27** : 89–93.

Young J H, Person N K, Donald J O and Mayfield W D, 1982. Harvesting curing and energy utilization. (*in*) *Peanut Science and Technology*. pp 458–85. Pattee and Young (eds). American Peanut Research and Education Society, Yoakum, Inc. Texas, USA.