Plant Archives Vol. 25, Supplement 2, 2025 pp. 433-439 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-2.052

EVALUATION OF GROUNDNUT FOR GROWTH, YIELD AND SEED QUALITY FOR CULTIVATION IN UTTARAKHAND HILL AGRO-ECOSYSTEM

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(Date of Receiving : 19-03-2025; Date of Acceptance : 27-05-2025)

ABSTRACT

This study was carried during 2022-23 and 2023-24 at Department of Seed Science and Technology, HNB Garhwal University, Chauras Campus, Srinagar (Garhwal), Uttarakhand with three Spanish groundnut (*Arachis hypogaea* L.) type cultivars *i.e.,* TG-37A, TG-51 and Avtar for evaluation of growth and development and yield potential for cultivation in lower Himalayan altitudes during two *kharif* seasons (2022 and 2023). These three varieties showed consistency in their early maturity, pod characteristics features, such as, single seeded, double seeded and triple seeded pods. Various seed physical and physiological parameters also exhibited more or less consistency over the years. Based on pod characteristics features, such as, reticulation, smoothness, beak or no beak, seed genetic purity was maintain in experimental plots, in addition to the rouging at various phenophases. Among three varieties TG-51 gave higher pod yield and HI during both the years. In addition, TG-51 showed higher number of single seeded pods in both the years. Seed physiological quality analysis exhibited that groundnut seed in-shell (pod) could be stored safely for >9 months with full vigour potential, as seed germinability was maintained >90% even after nine months of storage in all the three varieties. In conclusion, Spanish type groundnut with short crop duration, *i.e.,* maturing within 100-120 days are suitable for cultivation at lower Himalayan altitudes (600-1600 m).

***Keywords*:** Groundnut, Growth and development, Seed quality, Hill agro-ecosystem, Seed storability, Seed physical properties.

Introduction

Hill agriculture system is characterized by inaccessibility, fragility, marginality, heterogeneity and natural instability, thus becoming fragile for climate change impact. Different traditional crops are grown, including cereals, pulses, oilseeds and millets. The cropping pattern follows the sari system in which agricultural land is divided into two parts and in a set pattern crop are cultivated and in an alternate manner one side of land remain fallow at least for 4-5 months (Chandra *et al.*, 2020). The cropping pattern is mixed cropping following broadcasting sowing method (Ghosh & Dhyani, 2004). In general, agriculture has become non-profitable and labour consuming, therefore most of the farmers are following it as a sustenance agriculture. It was thought of importance to rejuvenate hill agriculture by following modern tools and techniques in a sustainable manner. Groundnut was selected to introduce in hill agriculture as it is high energy, multiutility cash crop and may help to boost the economy of resource poor farmers (Nautiyal & Mejia, 2002). In addition, groundnut has tremendous capacity to fix atmospheric nitrogen, thus helps in avoiding the heavy dose of synthetic fertilizers and maintain sustainability (Freeman *et al.*, 1999). On the other hand, there are several problems associated with groundnut cultivation, such as, availability of seed, because seed size is large and requires 100-120 kg ha^{-1} for sowing. In addition, low seed multiplication ratio (1:8) and poor storability makes the seed as costliest input (Singh *et al.*, 1998; Nautiyal & Mejia, 2002). Seed is stored as pod (in-shell) and seed quality is influenced by drying/curing methods (Nautiyal *et al.*,

1997, 2023). Since, in agriculture, timely availability of quality seed is the basic requirement to enhance productivity. Hence, it is necessary to maintain seed quality at least for 8-9 months, until commencement of sowing in next cropping season. Therefore, this study was aimed as pilot experiment to introduce groundnut cultivation in Uttarakhand hill region for nutritional food security, environmental sustainability, quality seed supply and improving socio-economic conditions of the local resource poor farmers.

Materials and Methods

Crop cultivation: Experiments were conducted with three varieties of groundnut *i.e.,* TG-37A, TG-51 and Avtar (ICGV-93468) in 2022 *kharif* season. Three cultivars were repeated for similar studies in 2023 *kharif* season. Experiments were conducted in plot size of 4 x 3 *m*, replicated three times. The spacing followed was 45 row-to-row and 10 cm plant-to-plant, seeds were sown at a depth of 5 cm. The experimental site is situated at 600 *m* elevation, soil is sandy loam and the location is characterized by low rainfall during *kharif* season. Nitrogen @ 20 kg ha^{-1}, phosphorous @ 40 kg ha^{-1} in the form of diammonium phosphate and potassium @ 0 kg ha^{-1} were applied before sowing in furrows. Standard agronomical practices including plant protection measures were followed to maintain healthy crop. Immediately after sowing, plots were irrigated to the field capacity and further irrigations was provided at regular intervals of about 8-10 days.

Harvest and post-harvest operations: Crop was harvested based on shell inside colouration, when 75 - 80% of plants showed maturity (Nautiyal *et al*., 2010; Nautiyal, 2009). Plants were harvested manually at 110 days in TG-37A and TG-51 and 120 days in Avtar 2022, while, during 2023 harvesting was performed at 105 and 115 days after sowing in both TG-37A, TG-51 and Avtar, respectively. After harvest, plants were clubbed in small bundles and dried in inverted position under field conditions for 2 to 3 days. Afterward, pods were picked and dried in thin layer under open sun for 4 to 5 days, until they attained moisture level <7-8%. Seed moisture was determined following gravimetrically in hot-air oven at 103±2˚C for 17±1 h following ISTA protocols (ISTA, 2023) and expressed on fresh weight basis.

Maintenance of seed physical purity: After through drying and cleaning, seeds were characterized for various physical parameters, during both the years for maintaining seed purity. Following parameters were studied, seed length, seed width, seed thickness, geometric mean diameter, aspect ratio, sphericity, surface area, bulk density, true density, porosity and seed index following standard methods (Mohscin, 1986; Fashina *et al*., 2014; Maduako & Faborode, 1990; Olajide & Igbeka, 2003; Farahmandfar *et al*., 2009). True density was determined using kerosene displacement method, while porosity was evaluated as porosity (%) = (1- Bulk density/true density) x 100 (Morita *et al*., 1979).

Seed storage: After harvest and through drying, seed lots obtained in both seasons were stored in polyethene (5 mm thickness) bags, and stored at ambient laboratory conditions. Seed lots were studied for germination and vigour potential during different period of storage.

Seed germination and vigour tests: Germination percentage was recorded following rolled towel paper method and 150 sound mature seeds were selected and sterilized with 1% sodium hypochlorite solution. Fifty seeds of each variety in three replications were arranged over the paper towel at equal distance and paper was rolled and tied with rubber band at the top following ISTA protocols (ISTA, 2023). The rolled papers were arranged in a beaker in vertical position. Beakers were finally placed in an incubator at 28±1˚C following Completely Randomized Block Design. Number of germinated seeds was recorded after seven days of incubation. Germination percentage, root length, shoot length and dry weight were measured on ten randomly selected seedlings from each replicate and seed vigour indices (SVI I and II) were calculated following Abdul Baki & Anderson (1973). The electrical conductivity (EC) of seed leachate was measured by soaking ten seeds in 25 ml of distilled water for 16 hours and expressed as µS cm^{-1}, replicated three times (Nautiyal & Zala, 1991).

Statistical analysis: Field experiments were conducted in Randomized Block Design (RBD), while, laboratory experiments were conducted in Completely Randomized Block Design (CRBD) following Gomez & Gomez (1984). Analysis of Variance (ANOVA) was calculated by using the statistical software which was developed by O. P. Sheoran, Computer Programmer at CCS HAU, Hisar, India, and critical difference was calculated.

Results and Discussion

Results of this study are described to explain suitability of cultivation of groundnut in hill agro-ecosystem and to maintain quality seed supply. Therefore, three varieties were tested in the *kharif* season of 2022 and were repeated for their performance in *kharif,* 2023. It was found that, short duration varieties have early harvest maturity *i.e.,* between 100 - 120 days in *kharif* season. In general,

growth, development and yield potential of identified varieties were at par with any of the groundnut growing areas. Thus, seed sown in the month of June with pre-monsoon shower or in the first week of July on arrival of monsoon may get sufficient time for crop maturity, *i.e.,* well before onset of winter. Further, seed storage studies showed that groundnut seeds may be used for the sowing for the next season crop.

Weather conditions*:* In general, it was found that there was less rainfall during 2022 *kharif* season, therefore crop was irrigated most frequently and even immediately after sowing. On the other hand, rainfall was more or less uniform during crop growth period, therefore was completely rain-dependent during 2023 (Table 1). In addition, maximum temperature was higher during the seed maturity in 2023 than 2022, hence crop maturity was early in 2023 than 2022.

Table 1 : Minimum temperature, maximum temperature, rainfall and relative humidity of Chauras region during *kharif* seasons of 2022 and 2023.

Month	2022				2023			
	Minimum temperature (˚C)	Maximum temperature (˚C)	Rainfall (mm)	Relative humidity (%)	Minimum temperature (˚C)	Maximum temperature (˚C)	Rainfall (mm)	Relative humidity (%)
June	23.0	36.4	6.5	62.83	23.2	36.1	12.3	63.55
July	23.6	33.8	11.5	82.16	23.1	33.4	22.8	84.19
August	23.3	32.5	1.0	75.57	23.1	32.9	13.3	84.97
September	22.4	31.3	13.8	83.45	23.4	33.6	2.5	77.33
October	16.9	28.6	0.5	73.91	16.1	30.2	15.5	75.57
November	12.1	24.5	0.5	79.98	11.6	25.8	0.3	79.93

Plant growth and development: Field emergence was observed early in TG-37A, TG-51 followed by Avtar, *i.e.,* between 5-7 days, during both the years. Flowering occurred between 25 and 40 days after sowing. Over all, crop duration in three varieties was shorter. Among the varieties, TG-51 achieved early physiological maturity than others, however, both TG-37A and TG-51 were harvested early than Avtar during both the years (Table 2). In addition, crop was completely rain-dependent in 2023, whereas, it was irrigated as and when required during 2022. In addition, crop was harvested at least 10 days late in *kharif* 2022 than 2023. This is attributed to high temperature and even rainfall pattern during the crop growth period in 2023 and deficit rainfall during 2022 (Table 1). Due to late season rain in 2022, 15-20% sprouting of pods/seed under field condition in TG-51 was recorded (data not presented). Such sprouting of pod/seed in Spanish cultivars due to lack of seed dormancy is already reported by Nautiyal *et al*. (2001).

Table 2 : Plant growth and development and harvest maturity in seven varieties of groundnut grown at HNBGU, Chauras campus during *kharif* seasons of 2022 and 2023.

Variety	Field emergence (75%)		Flowering (75%)		Physiological maturity (80%)		Harvest maturity	
	2022	2023	2022	2023	2022	2023	2022	2023
TG-37A	6	6	28	25	105	100	110	105
TG-51	5	7	30	25	100	100	105	105
Avtar	5	6	32	27	115	110	115	110
CD (V)	NS	NS	2.45	1.55	2.26	1.55	NS	1.55

CD (V) = Critical difference for variety; NS = non-significant

Crop yield and biomass: In 2022 pod yield was not varied significantly in three varieties, whereas biomass did not show significant difference. Pod yield ranged between 250 g m^{-1} in TG-37A and Avtar and 289 g m^{-2} in TG-51 (Table 3). In next *kharif* season pod yield in three potential varieties ranged between 276 and 302 g m^{-2}, being higher in TG-51 and Avtar followed by TG-37A (Table 3). Biomass production in all the varieties during both the years was non-significant, while HI was non-significant in 2022 and significant in 2023 (Table 3). The pod yield in three varieties was much more than the national average (1759 kg ha^{-1}) (GOI 2022). It is concluded that three varieties showed consistency in pod yield, biomass production and HI during both the *kharif* seasons (Table 3). In addition, these varieties are maturing within 100-115 days. This crop maturity period is favourable for cultivation of these potential varieties in local cropping system in *kharif s*eason. This mainly because that these varieties are maturing much before the onset of winter at this place (Table 2).

Table 3 : Pod yield, biomass, HI and characterization of pods for physical parameters in three varieties of groundnut grown at HNBGU, Chauras campus during *kharif* seasons of 2022 and 2023.

Varieties	Pod yield (g m^{-2})		Biomass (g m^{-2})		HI (%)		100 pod weights (g)		Number of seeds from 100 pods		Seed wt. (g) from 100 pods		Shell wt. (g) from 100 pods		Shelling outturn (%)		100-seed weight (g)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
TG-37A	250.0	275.6	575.9	712.0	43	39	121.9	124.2	192	197	90.8	92.2	31.0	31.8	74	74	49.9	49.7
TG-51	288.6	301.8	655.0	737.1	44	41	132.0	134.6	203	201	103.2	105.5	28.5	28.7	78	78	53.3	53.2
Avtar	250.4	289.9	586.9	760.5	43	38	129.3	129.8	187	189	94.5	94.9	34.4	34.4	73	73	56.2	56.7
CD (V)	NS	NS	NS	NS	NS	1.84	4.96	6.08	9.58	NS	3.90	4.55	1.28	1.50	0.44	0.31	3.65	1.42

CD (V) = Critical difference for variety; NS = non-significant

Morphological and physical characterization of pod and seed*:* Pod morphological and physical studies for two consecutive years showed that pod reticulation, pod constriction, beak, size and seed coat colour are consistently maintained in three potential varieties for two *kharif* seasons. For example, pod reticulation was absent in TG-37A, medium in TG-51 and prominent in Avtar, while, the pod constriction was absent in TG-37A, shallow in TG-51, medium in Avtar. Pod beak was present in all the varieties, while pod and seed size were medium in all the varieties (Table 4). In addition, two-seeded pods were abundant in all the varieties. The number of single and triple seeded pods, however, varied among the varieties. Among three varieties number of three seeded pods were higher in TG-51 in both the years (Fig 1). Parameters, such as, 100-pod weight, number of seeds from 100-pods, seed weight from 100-pods, shell weight from 100-pods, shelling outturn and 100-seed weight varied among the varieties, except for number of seeds from 100-pods in 2023 (Table 3). In addition, three potential varieties showed consistency in most of the parameters as mentioned above. Seed physical characteristics, such as, length, thickness, aspect ratio, porosity and true density varied significantly in two *kharif* seasons, whereas, seed width, geometric mean diameter, sphericity, surface area and bulk density did not vary significantly in both the years (Table 5). In general, seed width, thickness, geometric mean diameter, aspect ratio and surface area were recorded higher in TG-51. While, sphericity was similar in all the varieties. In addition, seed length, true density and porosity were recorded higher in Avtar (Table 5). All pod morphological characters showed distinctness in their features, indicating that these could be used in maintaining genetic purity, which is determinate to productivity (Salgado *et al*. 2006). In this study seed genetic purity was also maintained by performing monitoring and roughing at different phenological stages (Madhan & Nigam, 2013), as these characters are included in DUS testing programme (Hong *et al*., 2021).

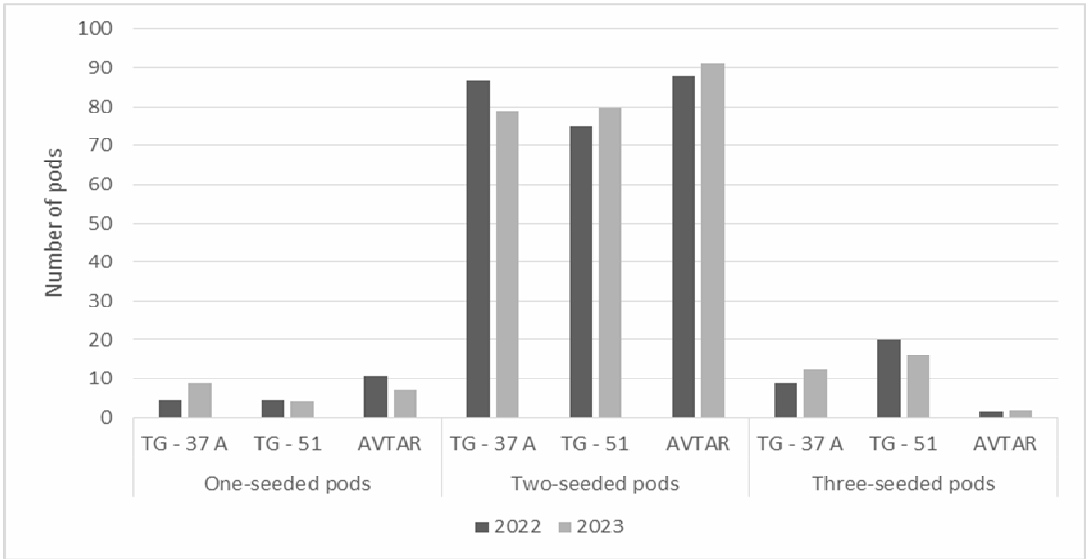

Fig. 1 : One-seeded, two-seeded and three-seeded pods in three varieties of groundnut grown at HNBGU, Chauras campus during *kharif* seasons of 2022 and 2023.

Table 4 : Morphological characterization of groundnut pods in five varieties of groundnut grown at HNBGU, Chauras campus during *kharif* seasons of 2022 and 2023.

Parameters	TG-37A	TG-51	Avtar	J-87	R-2001-3
Pod reticulation	Absent	Medium	Prominent	Medium	Prominent
Pod constriction	Absent	Shallow	Medium	Deep	Medium
Pod beak	Present	Present	Present	Present	Present
Pod size	Medium	Medium	Medium	Large	Small
Seed size	Medium	Medium	Medium	Bold	Small
Seed coat colour	Rose	Rose	Red	Monochrome rose	Rose

Table 5 : Seed physical characters, such as seed size, geometric mean diameter, aspect ratio, sphericity, surface area, bulk density, true density, porosity and seed index in three varieties of groundnut grown at HNBGU, Chauras campus during *kharif* seasons of 2022 and 2023.

Varieties	Length (mm)		Width (mm)		Thickness (mm)		Geometric mean diameter (mm)		Aspect ratio (%)		Sphericity (mm)		Surface area (mm^2)		Bulk density ($g\ cc^{-1}$)		True density ($g\ cc^{-1}$)		Porosity (%)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
TG-37A	13.7	13.4	8.8	8.7	8.0	8.0	9.9	9.8	63.9	64.7	0.7	0.7	305.9	299.7	0.7	0.7	1.0	1.0	36.6	37.8
TG-51	14.3	14.2	9.3	9.2	8.1	8.1	10.3	10.2	64.9	64.8	0.7	0.7	330.7	325.0	0.6	0.6	1.0	1.0	36.5	37.1
Avtar	14.6	14.8	9.0	9.0	7.9	7.6	10.1	10.0	61.5	60.7	0.7	0.7	320.3	316.7	0.6	0.6	1.2	1.2	44.6	44.9
CD (V)	0.18	0.88	NS	NS	NS	0.31	NS	NS	NS	3.45	NS	NS	NS	NS	NS	NS	0.12	0.10	4.33	3.20

CD (V) = Critical difference for variety; NS = non-significant

Influence of storage period on seed germinability and vigour: Seed germinability and vigour was monitored after through drying *i.e.,* after harvest and during storage up to nine months. The interaction of pod moisture content and genotype was significant in 2022 and non-significant in 2023. Similarly, interaction of storage period and variety was significant for seed moisture content, but it has not influenced germination percentage, seedling vigour indices (I and II) and EC of seed leachate in both the years (Table 6). This indicated that these parameters are not changing much in three potential varieties as they belong to the same botanical group. In addition, the critical difference (CD) for storage period and variety was significant during both the years for the parameters recorded. Among varieties pod moisture content during storage, ranged between 6 and 9%. Seed germination in all the varieties maintained >90%, even after 9 months of storage. Three varieties during 2023 exhibited higher germination percentage (>90%) than 2022 (Table 6). As seed germination percentage is closely associated with seed vigour indices, *i.e.,* SVI I and SVI II, it has not influenced seed vigour significantly during storage, indicating that loss in seed germination was much less than the prescribed limit of seed standard (*i.e.,* 70%). Thus, the three varieties showed higher vigour indices during both the years. Similarly, electrical conductivity of seed leachate was inversely associated with seed germinability and vigour, and was recorded higher Avtar with increasing storage period (Table 6). In general, seed vigour is the ability of seed to withstand harsh environmental conditions, while during storage, vigour was non significantly affected in all the varieties during both the years. The decline in seed quality during storage was mainly associated with seed moisture content and its interaction with outside environment, leading to seed membrane injuries by oxidative enzymes this results into loss of membrane permeability (Nautiyal *et al.*, 1998; Nautiyal & Mejia, 2002; Vasudevan *et al.*, 2014).

Table 6 : Influence of storage period on seed moisture content, germination (%), seedling vigour (SVI) I and II, and electrical conductivity of seed leachate (EC) of three varieties of groundnut grown at HNBGU, Chauras campus, Chauras, during two *kharif* seasons of 2022 and 2023.

Storage period	Variety	Seed mc (%)		Germination percentage (%)		SVI I		SVI II		EC (µS cm^{-1})	
		2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
0 M	TG-37A	8.5	8.6	95	98	1117	1115	45	45	0.013	0.013
	TG-51	8.9	8.5	96	93	1349	1361	44	46	0.020	0.020
	Avtar	8.0	7.0	94	94	1403	1383	51	51	0.027	0.023
9 M	TG-37A	6.9	7.2	92	95	999	996	38	39	0.037	0.030
	TG-51	6.3	6.1	93	91	1017	1046	38	38	0.040	0.033
	Avtar	7.5	6.6	91	93	1200	1204	47	46	0.050	0.047
Storage period (S)		0.20	0.14	1.20	1.96	82.76	84.35	1.27	1.70	0.006	0.005
Variety (V)		NS	0.17	NS	2.40	101.36	103.31	1.56	2.08	0.007	0.006
S x V		0.34	0.24	NS	NS	NS	NS	NS	NS	NS	NS

0 M= before storage; 9 M= after 9 months of storage; mc = moisture content; SVI = Seed Vigour Index; EC = Electrical conductivity; NS = non-significant

Conclusion

In conclusion, this study demonstrated that groundnut varieties, such as, TG-37A, TG-51 and Avtar, are having the crop duration well fitting in to the local *kharif* season cropping system. This could be utilized to enhance productivity and sustainability of hill agricultural system, as these varieties have the potential to change the socio-economic conditions of the local resource poor farmers.

Acknowledgement

Providing of seeds of groundnut varieties by ICAR-Directorate of Groundnut Research, Junagadh, Gujarat, India is gratefully acknowledged.

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