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Role of Pod and Seed Features in Determining *In situ* Germination in Groundnut (*Arachis hypogaea* L.)

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ABSTRACT: *In situ* germination (pre-harvest sprouting) in groundnut is an emerging constraint under changing climatic conditions, particularly in bunch-type cultivars lacking fresh seed dormancy. The present study examined the role of pod and seed morphological traits in governing *in situ* germination tolerance in selected sensitive and tolerant groundnut recombinant inbred lines (RILs), their parents, and two standard checks. Based on seed availability and mean *in situ* germination percentage recorded over *Kharif* 2022 and *Kharif* 2023, sixteen contrasting RILs along with parents and checks were evaluated for pod and seed traits during 2023. Among the traits assessed, pod wall thickness (PWT) emerged as the most critical determinant of *in situ* germination tolerance. Pod wall thickness exhibited wide and significant variation, ranging from 0.55 mm (N × T 278) to 1.55 mm (T × N 75). A strong inverse relationship was observed between PWT and *in situ* germination percentage (IGP). Tolerant genotypes possessing thicker pod walls (≥1.00 mm) recorded complete absence of *in situ* germination, whereas sensitive genotypes with thinner pod walls (<0.95 mm) showed high levels of sprouting (61–79%). In contrast, other pod and seed traits such as pod length, pod width, seed length, and seed width did not show any consistent association with *in situ* germination behaviour. These findings highlight pod wall thickness as a reliable phenotypic marker for selecting *in situ* germination–tolerant groundnut genotypes and provide valuable insights for breeding climate-resilient varieties.

Keywords: *In situ* germination, Pod wall thickness, Pre-harvest sprouting

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crops in India, contributing substantially to edible oil production, nutritional security, and farm income. India ranks as the second-largest producer of groundnut globally, with a cultivated area of 47.07 lakh hectares and a production of 101.80 lakh tonnes [1]. Groundnut seeds are nutritionally rich, containing 22–30% protein and 44–56% oil on a dry weight basis [2]. In addition to its economic importance, groundnut contributes to sustainable farming systems through biological nitrogen fixation and adaptability to diverse agro-ecologies. Despite these advantages, groundnut cultivation faces several production constraints, among which lack of fresh seed dormancy and vulnerability to *in situ* germination have emerged as major challenges under increasingly erratic climatic conditions.

In Spanish and Valencia bunch groundnut types, the absence or short duration of fresh seed dormancy predisposes mature pods to rain-induced sprouting when harvest coincides with unexpected rainfall and high soil moisture. Such *in situ* germination results in yield losses ranging from 20–50% in bunch groundnuts [3], and also causes deterioration in seed quality, oil content, processing value, and storability [4,5]. Climate change projections indicating increased frequency of unseasonal rainfall during crop maturity further aggravate this problem, especially in rainfed production systems where timely harvest is often constrained.

Seed dormancy in groundnut is a complex physiological trait regulated by endogenous hormonal balance, seed coat characteristics, and pod-mediated moisture dynamics. Abscisic acid (ABA) plays a central role in the induction and maintenance of seed dormancy by suppressing embryo growth potential and inhibiting the expression of germination-related enzymes. In freshly harvested groundnut seeds, higher ABA levels or increased sensitivity of the embryo to ABA delay radicle protrusion even under favourable moisture and temperature conditions. Conversely, reduced ABA concentration or enhanced gibberellin activity promotes rapid germination, increasing susceptibility to *in situ* sprouting under field conditions. The expression of dormancy is therefore determined not only by hormonal status but also by the physical environment surrounding the seed.

Pod and seed morphological traits, particularly pod wall thickness, strongly influence moisture diffusion kinetics into the pod cavity and seed surface. Thicker pod walls are hypothesised to slow the rate of water movement from the soil into the seed by increasing diffusion resistance and prolonging the time required to reach the critical moisture threshold necessary for germination. This delayed imbibition allows dormancy mechanisms mediated by ABA to remain effective, thereby preventing premature germination during transient wet conditions. In contrast, thin-walled pods facilitate rapid water ingress, leading to swift seed imbibition, dilution or leaching of ABA, and activation of metabolic processes associated with germination.

Apart from pod wall thickness, structural attributes such as pod reticulation, degree of constriction, and inner wall texture may further modify water retention and diffusion patterns within the pod. However, their influence on dormancy expression appears to be secondary and less consistent compared to pod wall thickness [6]. The combined effect of hormonal regulation and physical restriction of water uptake highlights the importance of integrating physiological and morphological perspectives when addressing *in situ* germination in groundnut.

Incorporation of fresh seed dormancy into high-yielding, farmer-preferred cultivars has therefore become a key breeding objective. Studies indicate that a dormancy period of approximately 3–4 weeks in Spanish bunch groundnut varieties is sufficient to protect against field sprouting under wet harvest conditions without compromising seed germination in the subsequent season [5]. However, direct selection for dormancy is challenging due to its polygenic nature, strong environmental modulation, and difficulties in phenotyping under uniform conditions. Morphological traits such as pod wall thickness, being genetically controlled, stable, and easily measurable, offer a practical surrogate for indirect selection of *in situ* germination tolerance.

In view of these considerations, the present investigation was undertaken to assess the contribution of pod and seed morphological traits to *in situ* germination behaviour in selected recombinant inbred lines of groundnut. By elucidating the relationship between pod wall thickness, moisture diffusion, and dormancy expression, the study aims to identify reliable phenotypic indicators that can be effectively deployed in breeding programmes targeting climate resilience, yield stability, and seed quality preservation.

METHODOLOGY

A total of 413 recombinant inbred lines (RILs) developed from a cross and reciprocal cross between TMV 2 and its near-isogenic dormant counterpart TMV 2-NLM [7,8] were initially evaluated for in situ germination on a plant basis. In addition to the RIL population, the parental lines TMV 2 (non-dormant) and TMV 2-NLM (dormant), along with two standard checks—dormant Dh 8 and non-dormant Dh 86—were included for comparison.

Field evaluations were conducted during the rainy (*Kharif*) seasons of 2022 and 2023 at the University of Agricultural Sciences, Dharwad. The experiment was laid out in an augmented design with four blocks, wherein the check varieties were replicated across blocks. Each genotype was sown in 1 m long rows at a spacing of 30 × 10 cm. The crop was raised following the recommended package of practices to ensure uniform growth and minimize management-related variation.

Based on seed availability and mean in situ germination percentage recorded over two seasons (*Kharif* 2022–*Kharif* 2023), eight highly tolerant and eight highly sensitive RILs were selected for detailed characterization in 2023. These selected RILs, along with the parents and one dormant and one non-dormant check, were evaluated for pod traits (pod reticulation, constriction, beak, pod length, pod width, pod wall thickness, and inner wall colour) and seed traits (seed length and seed width) following the groundnut descriptors [9].

Data recorded on pod and seed traits were subjected to statistical analysis using a Randomized Complete Block Design (RCBD) to test the significance of differences among genotypes.

RESULTS AND DISCUSSION

Variation in pod and seed morphological traits

The present investigation evaluated pod and seed morphological traits (Figure 1 and Table 1) in selected tolerant and sensitive groundnut lines, comprising 16 recombinant inbred lines (RILs), their parents, and two

Table 1. Pod and seed features of selected *In situ* tolerant and sensitive recombinant inbred lines (RILs), their parents, and checks of groundnut mapping population.

Sl. No.	Name of the RIL / Parent/ Checks			PL	PW	PWT	SL	SW	Pod Reticulation	Pod Beak	Pod Constriction	Inner Wall Colour	IGP
1	RIL1	TL	T X N 20	30.65	15.90	1.45	16.05	8.75	None	Absent	Absent	D to b	0.00
2	RIL2	TL	T X N 48	25.20	12.40	1.15	13.75	7.05	Prominent	Slight	Slight	W to cw	0.00
3	RIL3	TL	T X N 75	26.45	13.85	1.55	13.10	8.40	Prominent	Absent	Slight	D to b	0.00
4	RIL4	TL	T X N 91	28.70	11.55	1.15	12.20	8.20	Very prominent	Moderate	Moderate	D to b	0.00
5	RIL5	TL	N X T 7	26.80	10.70	1.00	11.90	7.20	Moderate	Slight	Moderate	W to cw	0.00
6	RIL6	TL	N X T 77	28.50	14.05	1.20	15.15	9.40	Moderate	Moderate	Moderate	D to b	0.00
7	RIL7	TL	N X T 143	29.50	13.50	1.05	14.30	6.75	Moderate	Prominent	Very deep	W to cw	0.00
8	RIL8	TL	N X T 181	27.40	11.90	1.15	12.25	9.55	Moderate	Slight	Moderate	W to cw	0.00
9	RIL9	SL	T X N 12	25.55	10.65	0.90	12.65	6.85	Prominent	None	None	W to cw	63.20
10	RIL10	SL	T X N 81	25.25	10.55	0.70	12.75	7.90	Prominent	None	Slight	D to b	73.98
11	RIL11	SL	N X T 49	27.20	10.15	0.80	11.20	8.00	Prominent	Slight	Slight	W to cw	66.97
12	RIL12	SL	N X T 144	29.35	11.00	0.75	15.40	6.85	Prominent	Moderate	Slight	W to cw	61.56
13	RIL13	SL	N X T 184	36.75	13.65	0.95	15.20	8.80	Very prominent	Prominent	Deep	D to b	56.59
14	RIL14	SL	N X T 278	25.05	8.95	0.55	10.30	8.10	Moderate	Slight	Moderate	W to cw	63.05
15	RIL15	SL	N X T 300	32.85	12.60	0.75	12.20	7.50	Prominent	Moderate	Deep	W to cw	66.59
16	RIL16	SL	N X T 308	30.30	12.20	0.75	15.35	8.50	Prominent	Moderate	Deep	W to cw	79.18
17	P1	P	TMV 2 NLM	33.95	14.50	1.15	16.45	7.00	Prominent	Prominent	Deep	W to cw	0.00
18	P2	P	TMV 2	24.20	11.70	0.70	11.35	7.30	Prominent	Slight	Moderate	D to b	25.72
19	C1	TC	DH 8	22.55	11.50	1.00	11.00	7.70	Slight	Slight	None	D to b	0.00
20	C2	SC	DH 86	27.60	11.35	0.65	13.10	9.35	Prominent	Slight	Slight	W to cw	55.51
			Mean	28.19	12.13	0.97	13.28	7.96					
			SEM±	0.61	0.30	0.05	0.40	0.27					
			CD @ 5%	1.74	0.85	0.15	1.15	0.76					
			CV (%)	3.74	4.23	9.26	5.23	5.81					

T × N : TMV 2 × TMV 2 NLM
N × T : TMV 2 NLM × TMV 2
RILs : Recombinant Inbred Lines
PWT : Pod Wall Thickness
W to cw : White to creamy white
P : Parent

PL : Pod Length
PW : Pod Width
SL : Seed Length
SW : Seed Width
D to b : Dark to brown

TL : Tolerant Line
SL : Sensitive Line
TC : Tolerant Check
SC : Sensitive Check
C : Check

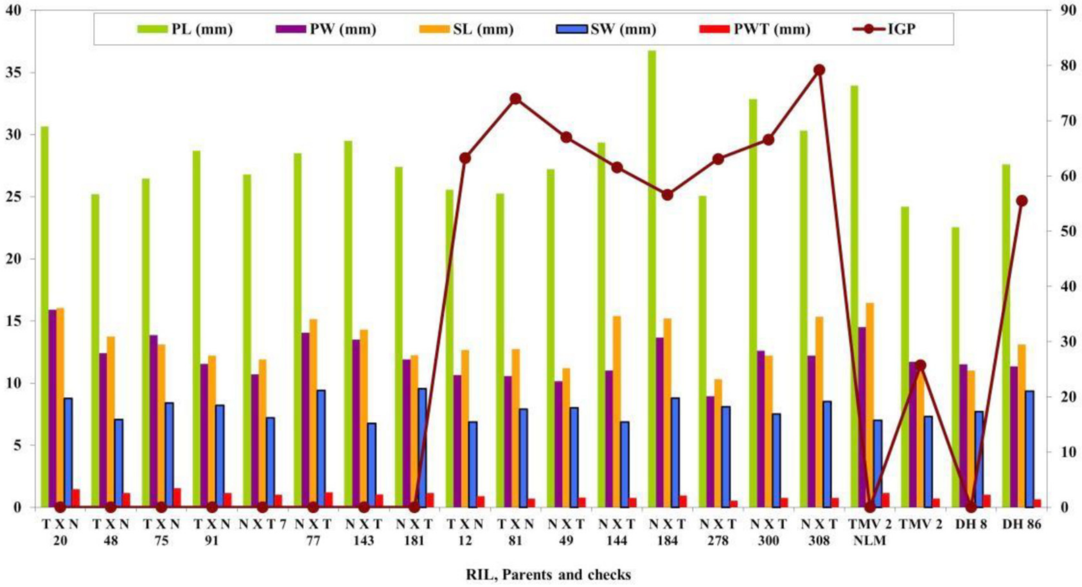

Figure 1. Pod and seed characteristics of selected *in situ* tolerant and sensitive recombinant inbred lines (RILs), their parents, and checks from the groundnut mapping population in relation to *in situ* germination

checks (one dormant and one non-dormant). Substantial variability was observed for pod wall thickness (PWT), whereas other pod and seed traits such as pod length, pod width, seed length, seed width, pod reticulation, constriction, beak, and inner wall colour exhibited relatively narrow ranges and lacked clear association with *in situ* germination behaviour.

Pod wall thickness varied significantly among the evaluated genotypes, ranging from 0.55 mm in N × T 278 to 1.55 mm in T × N 75. Based on *in situ* germination percentage (IGP), the RILs were clearly classified into tolerant and sensitive groups. Tolerant genotypes possessing higher PWT (≥1.00 mm) consistently recorded 0% *in situ* germination, whereas sensitive genotypes with reduced PWT (<0.95 mm) exhibited very high IGP, ranging from 61% to 79%. The non-dormant check Dh 86, characterized by a thin pod wall (0.65 mm), also showed high susceptibility to moisture-induced sprouting, reinforcing the critical role of PWT in conferring tolerance.

Pod wall thickness as a physical regulator of moisture diffusion

The strong negative association between pod wall thickness and *in situ* germination suggests that PWT functions as a primary physical barrier regulating moisture diffusion into the pod cavity. Thicker pod walls increase diffusion resistance, thereby slowing water movement from the soil into the seed microenvironment. This delayed imbibition prevents the seed from reaching the critical moisture threshold required to initiate germination during short periods of soil saturation following unseasonal rainfall.

In contrast, thin-walled pods allow rapid water ingress, resulting in quick seed hydration and activation of germination-related metabolic processes. Similar relationships between pod wall thickness and pre-harvest sprouting have been reported in mung bean, where thicker pod walls and higher epicuticular wax content were negatively associated with sprouting under wet conditions [10]. Earlier studies in mung bean [11,12] and groundnut [6] also documented increased pre-harvest sprouting with decreasing pod wall thickness, supporting the findings of the present study.

Interaction of pod wall thickness with hormonal regulation of dormancy

Beyond its physical role, pod wall thickness indirectly modulates the physiological mechanisms governing seed dormancy, particularly those mediated by abscisic acid (ABA). In freshly harvested groundnut seeds, ABA plays a central role in maintaining dormancy by inhibiting embryo growth, suppressing hydrolytic enzyme activity, and preventing radicle protrusion. In tolerant genotypes with thicker pod walls, restricted and slower moisture uptake likely preserves higher endogenous ABA levels or maintains embryo sensitivity to ABA for a longer duration, thereby reinforcing dormancy expression even under favourable moisture conditions.

Conversely, in sensitive genotypes with thin pod walls, rapid imbibition may lead to dilution or leaching of ABA and an increase in embryo growth potential, resulting in early dormancy release and *in situ* germination. Thus, the observed differences in germination behaviour among RILs appear to be governed by a combined effect of physical restriction of water entry and hormonal control of germination, wherein pod wall thickness acts as a critical upstream regulator.

Limited role of other pod and seed traits

Other pod and seed traits, including pod length (22.55–36.75 mm), pod width (8.95–15.90 mm), seed length (10.30–16.45 mm), and seed width (6.75–9.55 mm), did not show any consistent association with *in situ* germination tolerance. Similarly, qualitative traits such as pod reticulation, pod beak presence, pod constriction, and inner wall colour, though variable among genotypes, failed to influence germination behaviour under wet conditions.

These observations indicate that traits related to pod and seed size primarily affect yield components and market preference rather than dormancy expression or sprouting tolerance. The absence of correlation between seed size and *in situ* germination further suggests that moisture regulation at the pod level, rather than intrinsic seed dimensions, is the dominant factor governing sprouting behaviour in groundnut.

Implications for breeding and climate resilience

The clear differentiation between tolerant and sensitive genotypes based on pod wall thickness highlights its value as a reliable phenotypic indicator for *in situ* germination tolerance. Given the difficulty of directly phenotyping fresh seed dormancy due to environmental variability, PWT offers a practical and stable surrogate trait for selection in breeding programmes. The use of pod wall thickness as a selection criterion can facilitate the development of climate-resilient groundnut cultivars capable of withstanding unseasonal rainfall during crop maturity.

Overall, the findings of the present study demonstrate that tolerance to *in situ* germination in groundnut is governed by an integrated mechanism involving pod-mediated moisture diffusion and ABA-regulated dormancy expression. Selection for thicker pod walls in elite breeding material could therefore contribute significantly to reducing harvest losses, improving seed quality, and stabilizing yield under increasingly unpredictable climatic conditions.

CONCLUSION

The present study unequivocally establishes pod wall thickness as the principal morphological trait conferring tolerance to *in situ* germination in groundnut. Genotypes with thicker pod walls effectively resisted moisture-induced sprouting, thereby safeguarding seed quality and stabilizing yield under conditions of unseasonal rainfall at maturity. Since other pod and seed traits showed no significant association with *in situ* germination behaviour, breeding efforts aimed at developing tolerant groundnut varieties can primarily focus on pod wall thickness as a reliable and easily measurable selection parameter. Incorporation of this trait into high-yielding, farmer-preferred backgrounds will be instrumental in mitigating climate-related harvest losses and enhancing the resilience of groundnut production systems.

REFERENCES

1. AGRICULTURAL MARKET INTELLIGENCE CENTRE (2025). PJTAU, Groundnut Outlook: 1-3.
2. SAVAGE GP AND JI KEENAN (1994). The composition and nutritive value of groundnut seeds. In: Smart J. (ed.), The groundnut crop, A scientific basis for improvement. Chapman & Hall, / London / New York. Science, **39**: 52-56.
3. NAGARJUN P AND GD RADDER (1983). Studies on induction of seed dormancy in bunch type groundnut. *Seed Research*, **11 (1)**: 24.
4. REDDY PS, VR ZADE AND SN DESHMUKH (1985). CGSI-19: A new Spanish bunch groundnut cultivar with fresh seed dormancy. *Journal of Oilseeds Research*, **2**: 103-106.
5. PATRO HK AND M RAY (2016). Seed dormancy in groundnut-A review. International Journal of Tropical Agriculture, **34(1)**: 31-37.
6. AKSHATA (2022). Investigation on influence of accelerated ageing on seed quality and assessment of In situ germination in groundnut (*Arachis hypogaea* L.) genotypes, M.Sc. (Agri.) thesis, University of Agricultural Sciences Dharwad, 1-112.
7. PATTANASHETTI SK (2005). Genetic analysis of mutational origin of diversity in groundnut (*Arachis hypogaea* L.). University of Agricultural Sciences, Dharwad, India.
8. HAKE AA, K SHIRASAWA, A Yadawad, M Sukruth, M Patil, SN Nayak, S Lingaraju, PV Patil, HL Nadaf, MVC Gowda, RS Bhat (2017). Mapping of important taxonomic and productivity traits using genic and non-genic trans posable element markers in peanut (*Arachis hypogaea* L.). *PLoS One* **12(10)**: e0186113. https://doi.org/10.1371/journal.pone.0186113.
9. IBPGR/ICRISAT (1992). Descriptors for groundnut. International board of plant genetic resources and international crops research institute for the semi-arid tropics, Rome, Italy and Patancheru, Andhra Pradesh, India.

10. MOGALI S, NKB PATIL, H RANJITA, G BALOL, L JAGGAL (2023). Development of mungbean genotypes for shattering tolerance and correlation analysis with biochemical and morphological factors governing pre harvest sprouting. *Legume Research*. Epub ahead of print 23 April 2023 DOI 10.18805/LR-5089.

11. CHERALU C, A SATYANARAYANA, N KULKARNI, K JAGDISHWAR AND MSS REDDY (1999). Combining ability analysis for resistance to pre-harvest sprouting in mungbean (*Vigna radiata* (L) Wilczek). *Indian Journal of Genetics and Plant Breeding*, **59(4)**: 465-472.

12. ANUPAMA S, RK KHULBE AND RK PANWAR (2012). Evaluation of urdbean (*Vigna mungo*) germ plasm for pre-harvest sprouting tolerance. *Journal of Food Legumes*, **25(3)**: 183-186.