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PREDICTIVE ABILITY OF SEED VIGOUR ASSESSMENT METHODS FOR FIELD EMERGENCE IN GROUNDNUT (*ARACHIS HYPOGAEA* L.)

Rubeena Afreen[1*], K. Lakshmiprasanna[1], P. Sujatha[2], P. Jagan Mohan Rao[3]
[1]Department of Seed Science and Technology, College of Agriculture, Rajendranagar, PJTAU, Hyderabad, 500030, Telangana, India
[2]DepartmentSeed Science and Technology, Agricultural College, Polasa, Jagtial, 505327, India
[3]Department of Genetics and Plant Breeding, College of Agriculture, Rajendranagar, PJTAU, Hyderabad, 500030, Telangana, India
*Corresponding author E-mail: rubeena3812@gmail.com
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ABSTRACT

The present study was undertaken to assess the predictive ability of different seed vigour assessment methods for field emergence in groundnut (*Arachis hypogaea* L.). Seed vigour of three groundnut varieties (K-6, KL-1812 and GJG-32), comprising four seed lots per variety, was evaluated using physical, physiological, stress tests under laboratory conditions. Significant variation was observed among varieties and seed lots for most vigour parameters. Among the varieties, KL-1812 consistently exhibited superior seed vigour, as evidenced by higher germination percentage, seedling vigour indices, radicle emergence and field emergence, followed by K-6, while GJG-32 recorded comparatively lower vigour. Stress vigour tests and biochemical assays effectively differentiated high- and low-vigour seed lots. Correlation analysis revealed that several laboratory vigour parameters were strongly associated with field emergence, except seedling length and seedling vigour index I demonstrating their effectiveness in predicting field performance. The study highlights that integrating multiple seed vigour assessment methods provides a reliable and practical approach for predicting field emergence and overall seed quality in groundnut.
***Keywords* :** Groundnut, Vigour, Stress tests, Radicle emergence, Field emergence.

Introduction

Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed and food legume crops globally, valued for its high oil, protein, and calorific content. Successful crop establishment in groundnut is largely dependent on the physiological quality of seed, particularly seed vigour, which governs the rate and uniformity of germination, seedling growth, and field emergence under diverse environmental conditions (Abdul-Baki and Anderson, 1973; Copeland and McDonald, 2001). Even when seed lots meet the prescribed germination standards, poor vigour often results in delayed emergence, uneven plant stand, and yield reduction.

Seed vigour is defined as the sum of those seed properties that determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions (ISTA, 2023). Unlike standard germination tests, which assess seed performance under optimal laboratory conditions, vigour tests are designed to reveal subtle differences in seed quality that influence field performance, especially under sub-optimal or stress conditions (Delouche and Baskin, 1973; Powell, 2006). This distinction is particularly important in groundnut, a crop highly susceptible to seed deterioration due to its high lipid content, membrane instability, and vulnerability to mechanical damage during harvesting and handling (McDonald, 1999).

Several physical, physiological, stress, and biochemical vigour assessment methods have been developed to evaluate different components of seed quality. Physiological tests such as seedling vigour indices and radicle emergence provide insight into early seedling growth potential, while stress tests like accelerated ageing simulate storage-related deterioration and help predict field emergence under adverse conditions (Hampton and TeKrony, 1995; Powell and Matthews, 2012). Biochemical tests, including electrical conductivity and assays of enzymatic activity, reflect membrane integrity and metabolic efficiency, which are closely associated with seed deterioration and vigour loss (Bewley *et al*., 2013).

Although individual vigour tests have been reported to correlate with field emergence, their effectiveness varies with species, genotype, and seed lot characteristics (Hampton, 2002). In groundnut, information on the comparative evaluation of multiple vigour assessment methods and their predictive ability for field emergence across different varieties and seed lots remains limited. Identifying reliable laboratory-based indicators that accurately reflect field performance is essential for improving seed quality evaluation, storage management, and planting value assessment.

Therefore, the present investigation was undertaken to evaluate seed vigour among different groundnut varieties and seed lots using physical, physiological, stress, and biochemical vigour tests, and to assess their predictive ability for field emergence. The study aims to establish meaningful relationships between laboratory vigour parameters and field performance, thereby providing a comprehensive and reliable approach for evaluating seed quality in groundnut.

Materials and Methods

Experimental Material

The experimental material consisted of three groundnut (*Arachis hypogaea* L.) varieties, namely K-6, Kadiri Lepakshi-1812 (KL-1812), and GJG-32, obtained from the Rabi 2023 sown crop. Four seed lots of each variety were used for the study. The experiment was conducted under laboratory and field conditions to evaluate seed vigour and its relationship with field emergence.

Physical Seed Quality Parameters

Physical seed quality parameters were assessed to determine seed size, weight, and soundness. Seed length, width, and thickness were measured using a Vernier caliper, and the average values were expressed in millimeters. Hundred-seed weight was recorded using an electronic balance and expressed in grams. Physical soundness was assessed based on visual examination of seeds, and the proportion of physically sound seeds was recorded. Seeds that were shrivelled, undersized, poorly developed, discoloured, cracked, or insect-damaged were categorized as weak seeds and excluded from the sound seed count.

Physiological Vigour Assessment

Physiological seed vigour was evaluated using standard germination and seedling growth parameters. Germination test was conducted following the procedures prescribed by the International Seed Testing Association (ISTA, 2022), and germination percentage was recorded. First count of germination was taken as per ISTA rules. Speed of germination was calculated using the formula proposed by Maguire (1962).

Seedling growth parameters such as seedling length (cm) and seedling dry weight (mg) were recorded using normal seedlings obtained from the germination test. Seedling dry weight was determined after oven-drying the seedlings at 80 ± 2 °C for 24 h. Seedling vigour index I (germination percentage × seedling length) and seedling vigour index II (germination percentage × seedling dry weight) were calculated following Abdul-Baki and Anderson (1973). Seed metabolic efficiency was estimated as described by Rao and Sinha (1993) to assess the efficiency of reserve utilization during early seedling growth.

Stress Vigour Tests

Stress vigour of seed lots was assessed using radicle emergence, accelerated ageing, controlled deterioration, and field emergence tests. Radicle emergence was expressed as the percentage of seeds exhibiting visible radicle protrusion within a specified time after exposure to cold stress under standard germination conditions.

Accelerated ageing test was carried out by exposing seeds to a temperature of 40 ± 1 °C and 95 per cent relative humidity for 120 h, following which standard germination test was conducted. Controlled deterioration test was performed by adjusting seed moisture content and subjecting the seeds to high temperature conditions (41–45 °C) for durations ranging from 24 to 72 h, after which germination and electrical conductivity of seed was assessed.

Field emergence test was conducted under field conditions to evaluate the actual emergence potential of seed lots. Emergence percentage was recorded based on the number of seedlings emerged and established under field conditions, following the method described by Shenoy *et al*. (1990).

Results and Discussions

Physical Vigour Parameters

Significant differences were observed among groundnut varieties, seed lots, and their interactions for most physical vigour parameters, indicating the combined influence of genetic constitution and lot-specific factors (Table 1). Seed length, width, and thickness showed highly significant varietal effects, with KL-1812 (V2) consistently recording superior values compared to K-6 (V1) and GJG-32 (V3). The greater seed dimensions of KL-1812 (L=13.82, W= 9.26, T=7.61 mm) reflect its inherent genetic potential for better seed filling and accumulation of storage reserves (Fig 1). Although minor variations were observed among seed lots, mean values across lots were narrow, suggesting that seed size traits are predominantly under genetic control with limited environmental modulation. Similar observations on the genetic regulation of seed size and its association with vigour have been reported earlier (Archana Sanyal and Joshi, 2016; Ankaiah *et al*., 2013).

Physical soundness differed significantly among varieties but not among seed lots or their interaction, further emphasizing strong varietal control (Table 2). KL-1812 exhibited the highest physical soundness (98 %), likely due to its harder seed coat and compact seed structure, which confer resistance to mechanical injury. The stability of physical soundness across lots supports earlier reports that this trait remains relatively unaffected by lot variations and plays a key role in maintaining seed vigour and germination potential (Gowda, 2017).

Similarly, 100-seed weight showed significant varietal differences, with KL-1812 (56.30 g) and K-6 (45.70 g) recording higher seed weights than GJG-32 (38.00 g). Minimal lot-wise variation indicated uniform seed development across lots. Higher seed weight has been widely associated with superior seed vigour, enhanced reserve availability, and improved field establishment, as also reported in millets and oilseed crops (Rai *et al*., 2017; Rawat *et al*., 2023). Overall, the superior physical vigour attributes of KL-1812 explain its better performance in subsequent physiological and stress vigour tests.

Physiological Vigour Parameters

Physiological vigour tests revealed clear varietal differences in germination behaviour and early seedling growth (Table 3). First count of germination and speed of germination were significantly higher in KL-1812 (83 % and 22.95 respectively) and K-6 (82 % and 23.50 respectively), indicating faster metabolic activation and efficient mobilization of seed reserves (Fig 2). The limited variation among seed lots and non-significant interactions for speed of germination suggest that this parameter is largely governed by genetic factors. These findings corroborate earlier studies highlighting first count and germination speed as reliable indicators of seed vigour and early field performance (Kata *et al*., 2014; Bajpai *et al*., 2015; Chandanasree *et al*., 2024).

Final germination percentage also differed significantly among varieties, with KL-1812 (92 %) recording the highest viability, followed by K-6 (87 %), while GJG-32 exhibited comparatively lower germination (83 %). This trend reflects differences in physiological quality and reserve utilization efficiency among genotypes. Similar varietal differences in groundnut germination have been reported by Hiremath *et al*. (2024).

Seedling growth parameters further supported varietal distinctions. Seedling length was highest in GJG-32 (15.01 cm), indicating rapid elongation, whereas KL-1812 recorded the highest seedling dry weight (550.00 mg), reflecting superior biomass accumulation. This contrast suggests that while GJG-32 favoured elongation growth, KL-1812 exhibited more efficient conversion of reserves into dry matter. Previous studies have emphasized that seedling dry weight is a more reliable indicator of vigour than seedling length alone, as it directly reflects reserve mobilization efficiency (Vasudevan *et al*., 2014; Rai *et al*., 2017; Choudhary *et al*., 2024).

Seedling Vigour Index-I and II showed significant varietal and lot-wise variations (Table 4). Although GJG-32 recorded higher SVI-I (1292) due to longer seedlings, KL-1812 exhibited the highest SVI-II (50594) owing to superior germination and seedling dry weight. This indicates that SVI-II is more closely associated with physiological robustness and field performance than SVI-I. Similar conclusions have been drawn in finger millet, barnyard millet, and redgram (Rawat *et al*., 2023; Hiremath *et al*., 2024).

Seed mobilization efficiency (SME) further differentiated varieties, with KL-1812 showing the highest efficiency (78 %), followed by K-6 (75 %), while GJG-32 recorded the lowest (60 %). Higher SME reflects effective enzymatic activity and efficient translocation of seed reserves to growing seedlings. The significant variety × lot interaction observed for SME indicates that while genetic factors predominate, favourable lot conditions can enhance reserve utilization. These results align with Padilha *et al*. (2020), who reported SME as a strong indicator of internal seed quality and vigour potential.

Stress Vigour Parameters

Stress vigour tests clearly distinguished varietal tolerance under adverse conditions (Table 5). Radicle emergence was significantly higher in K-6 (76 %) and KL-1812 (76 %), reflecting faster initiation of germination and superior metabolic stability under stress. Minimal lot-wise variation indicated uniform seed integrity across lots (Fig 3). Radicle emergence has been recognized as a rapid and cost-effective vigour test for predicting early germination potential (Matthews *et al*., 2018).

Accelerated ageing and controlled deterioration tests revealed marked varietal differences in storability and stress tolerance. K-6 exhibited the highest tolerance under both tests, followed by KL-1812, while GJG-32 deteriorated rapidly. These differences may be attributed to variation in membrane stability, antioxidant defence mechanisms, and seed coat characteristics. The reliability of accelerated ageing and controlled deterioration tests for assessing vigour and storability in groundnut has been well documented (Santorum *et al*., 2013; Vaz Coelho *et al*., 2022).

Electrical conductivity values further supported these observations, with K-6 recording the lowest leakage (15.08 µS/cm/g), indicating better membrane integrity, whereas GJG-32 showed the highest solute leakage (72.54 µS/cm/g), reflecting advanced membrane damage. Electrical conductivity has been widely accepted as a sensitive indicator of seed deterioration and vigour loss across crops such as soybean, chickpea, and sunflower (Colette *et al*., 2004; Araujo *et al*., 2022).

Field emergence, which reflects the cumulative effect of all seed vigour components, exhibited significant differences among varieties and seed lots (Table 6). KL-1812 recorded the highest field emergence (88%), followed by K-6 (82%), whereas GJG-32 showed poor establishment (65%). The close agreement between laboratory vigour test results and field emergence confirms the reliability and effectiveness of the vigour assessment methods employed. Except for seedling length and seedling vigour index I, all other evaluated parameters showed a positive and significant correlation with field emergence. Similar relationships between laboratory vigour parameters and field emergence have previously been reported in groundnut by Poonguzhali and Kanagarasu (2015).

Conclusion

The present investigation clearly demonstrated significant varietal differences in physical, physiological, and stress-related seed vigour parameters of groundnut, with comparatively limited influence of seed lots for most traits. Among the varieties evaluated, KL-1812 consistently exhibited superior physical attributes, higher germination potential, greater seedling dry matter accumulation, efficient seed reserve mobilization, and better tolerance to stress conditions, which collectively translated into the highest field emergence. K-6 also performed well, particularly under accelerated ageing, controlled deterioration, and electrical conductivity tests, indicating strong storability and membrane integrity. In contrast, GJG-32 showed comparatively inferior performance in most vigour parameters and field establishment, despite exhibiting greater seedling elongation.

The strong association between laboratory vigour tests and field emergence confirms the reliability of these assessments for predicting field performance in groundnut. Except for seedling length and seedling vigour index I, all parameters showed a positive and significant correlation with field emergence, emphasizing the greater relevance of traits related to reserve mobilization, membrane integrity, and stress tolerance.

Table 1 : Seed size parameters (length, width and thickness) in groundnut varieties and lots

	Seed length (mm)					**Seed width (mm)**					**Seed thickness (mm)**				
Lots / Varieties	**L1**	**L2**	**L3**	**L4**	**Mean**	**L1**	**L2**	**L3**	**L4**	**Mean**	**L1**	**L2**	**L3**	**L4**	**Mean**
V1	12.60	12.80	12.30	13.00	12.67	8.44	8.58	8.24	8.71	8.49	6.93	7.03	6.77	7.15	6.97
V2	13.80	13.70	13.90	13.90	13.82	9.25	9.18	9.31	9.31	9.26	7.59	7.54	7.65	7.65	7.61
V3	11.60	11.40	11.20	10.90	11.28	7.77	7.64	7.50	7.30	7.55	6.38	6.27	6.61	6.00	6.20
Mean	12.66	12.63	12.46	12.60	12.59	8.48	8.46	8.35	8.44	8.43	6.96	6.94	6.86	6.93	6.92
	V	**L**	**VL**			**V**	**L**	**VL**			**V**	**L**	**VL**		
CD (0.05)	0.08*	0.09*	0.16*			0.05*	0.06*	0.11*			0.04*	0.05*	0.09*		
SE(m)	0.02	0.03	0.05			0.02	0.02	0.04			0.01	0.01	0.03		
CV %	0.79					0.83					0.82				

Note: *- Significant at 5%; V1 –K6, V2-KL 1812, V3- GJG 32; L1-Lot 1, L2-Lot 2, L3-Lot 3, L4- Lot 4

Table 2 : Physical and early germination attributes of groundnut varieties and lots

Lots / Varieties	Physical soundness (%)					100 Seed weight (g)					First count (%)				
	L1	**L2**	**L3**	**L4**	**Mean**	**L1**	**L2**	**L3**	**L4**	**Mean**	**L1**	**L2**	**L3**	**L4**	**Mean**
V1	97	97	96	97	97	45.54	46.26	43.27	47.77	45.70	81	81	78	87	82
V2	98	98	98	98	98	55.86	55.67	56.92	56.64	56.30	86	86	82	79	83
V3	95	94	94	93	94	40.89	39.19	38.15	33.95	38.00	73	75	76	75	75
Mean	97	96	96	96	96	47.43	47.04	46.11	46.12	46.67	80	81	79	80	80
	V	**L**	**VL**			**V**	**L**	**VL**			**V**	**L**	**VL**		
CD (0.05)	0.79*	0.91	1.58			0.49*	0.56*	0.98*			1.14*	1.32*	2.29*		
SE(m)	0.27	0.31	0.54			0.16	0.19	0.33			0.39	0.45	0.78		
CV %	0.98					1.25					1.70				

Note: *- Significant at 5%; V1 –K6, V2-KL 1812, V3- GJG 32; L1-Lot 1, L2-Lot 2, L3-Lot 3, L4- Lot 4

Table 3 : Germination and seedling growth parameters of groundnut varieties and lots

Lots / Varieties	Seedling dry weight (mg)					Seedling vigour index-I					Seedling vigour index-II				
	L1	**L2**	**L3**	**L4**	**Mean**	**L1**	**L2**	**L3**	**L4**	**Mean**	**L1**	**L2**	**L3**	**L4**	**Mean**
V1	444.30	470.30	466.30	451.30	458.00	1207	1174	1191	1401	1243	38357	39832	38229	42694	39778
V2	556.70	593.70	530.30	519.00	550.00	1232	1219	1309	1274	1258	50156	54601	49714	47904	50594
V3	371.30	316.70	384.00	324.30	349.00	1262	1239	1407	1259	1292	30713	26583	31866	26725	28972
Mean	457.40	460.20	460.20	431.60	452.33	1233	1210	1302	1311	1264	39742	40339	39937	39108	39781
	V	**L**	**VL**			**V**	**L**	**VL**			**V**	**L**	**VL**		
CD (0.05)	37.96*	43.3	75.92			78.27	90.38	156.54			3589.37*	4144.65	7178.74		
SE(m)	13.00	15.01	26.00			26.82	30.96	53.63			1229.73	1419.98	2459.47		
CV %	9.95					7.34					10.70				

Table 4 Seedling vigour parameters of groundnut varieties and lots

Lots / Varieties	Seedling dry weight (mg)					Seedling vigour index-I					Seedling vigour index-II				
	L1	**L2**	**L3**	**L4**	**Mean**	**L1**	**L2**	**L3**	**L4**	**Mean**	**L1**	**L2**	**L3**	**L4**	**Mean**
V1	444.30	470.30	466.30	451.30	458.00	1207	1174	1191	1401	1243	38357	39832	38229	42694	39778
V2	556.70	593.70	530.30	519.00	550.00	1232	1219	1309	1274	1258	50156	54601	49714	47904	50594
V3	371.30	316.70	384.00	324.30	349.00	1262	1239	1407	1259	1292	30713	26583	31866	26725	28972
Mean	457.40	460.20	460.20	431.60	452.33	1233	1210	1302	1311	1264	39742	40339	39937	39108	39781
	V	**L**	**VL**			**V**	**L**	**VL**			**V**	**L**	**VL**		
CD (0.05)	37.96*	43.3	75.92			78.27	90.38	156.54			3589.37*	4144.65	7178.74		
SE(m)	13.00	15.01	26.00			26.82	30.96	53.63			1229.73	1419.98	2459.47		
CV %	9.95					7.34					10.70				

Note: *- Significant at 5%; V1 –K6, V2-KL 1812, V3- GJG 32; L1-Lot 1, L2-Lot 2, L3-Lot 3, L4- Lot 4

Table 5 : Stress and reserve mobilization parameters of groundnut varieties

Varieties / Lots	Seed mobilization efficiency (%)					Radicle emergence (%)					Accelerated ageing (%)				
	L1	**L2**	**L3**	**L4**	**Mean**	**L1**	**L2**	**L3**	**L4**	**Mean**	**L1**	**L2**	**L3**	**L4**	**Mean**
V1	66	78	75	81	75	77	75	72	81	76	70	72	72	78	73
V2	93	90	68	67	78	81	76	75	71	76	45	46	49	44	46
V3	68	50	69	54	60	56	57	56	56	56	29	29	30	28	29
Mean	76	73	71	67	71	71	69	68	70	69	48	49	50	50	49
	V	**L**	**VL**			**V**	**L**	**VL**			**V**	**L**	**VL**		
CD (0.05)	5.55*	6.40	11.10*			1.54*	1.78*	3.08*			1.92*	2.22	3.85*		
SE(m)	1.90	2.19	3.80			0.52	0.61	1.05			0.66	0.76	1.31		
CV %	9.20					2.64					4.62				

Note: *- Significant at 5%; V1 –K6, V2-KL 1812, V3- GJG 32; L1-Lot 1, L2-Lot 2, L3-Lot 3, L4- Lot 4

Table 6 : Variation in controlled deterioration response, electrical conductivity and field emergence among different lots of groundnut varieties

	Controlled deterioration (%)					Controlled deterioration EC (µS/cm/g)					Field emergence (%)				
Varieties / Lots	**L1**	**L2**	**L3**	**L4**	**Mean**	**L1**	**L2**	**L3**	**L4**	**Mean**	**L1**	**L2**	**L3**	**L4**	**Mean**
V1	57	61	63	66	62	15.73	18.12	11.76	14.70	15.08	80	78	77	92	82
V2	47	43	42	43	44	21.61	24.31	24.55	40.35	27.71	88	90	87	86	88
V3	12	14	12	9	12	73.31	67.78	78.48	70.58	72.54	64	66	68	61	65
Mean	39	39	39	39	39	36.88	36.74	38.27	41.87	38.44	77	78	77	80	78
	V	**L**	**VL**			**V**	**L**	**VL**			**V**	**L**	**VL**		
CD (0.05)	2.13*	2.46	4.26*			0.30*	0.35*	0.60*			1.10*	1.27*	2.21*		
SE(m)	0.73	0.84	1.46			0.10	0.12	0.20			0.37	0.43	0.75		
CV %	6.47					0.93					1.67				

Note: *- Significant at 5%; V1 –K6, V2-KL 1812, V3- GJG 32; L1-Lot 1, L2-Lot 2, L3-Lot 3, L4- Lot 4

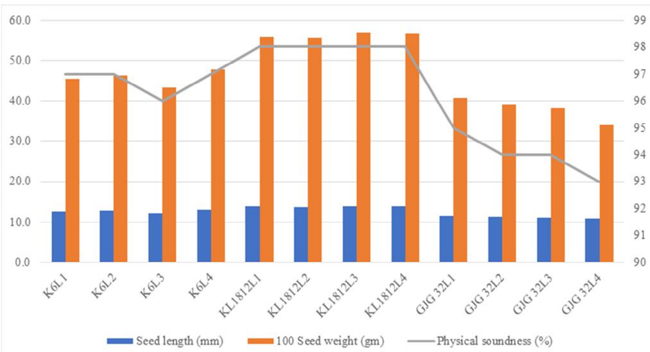

Fig. 1 : Physical Vigour Characteristics of Groundnut Varieties and Seed Lots

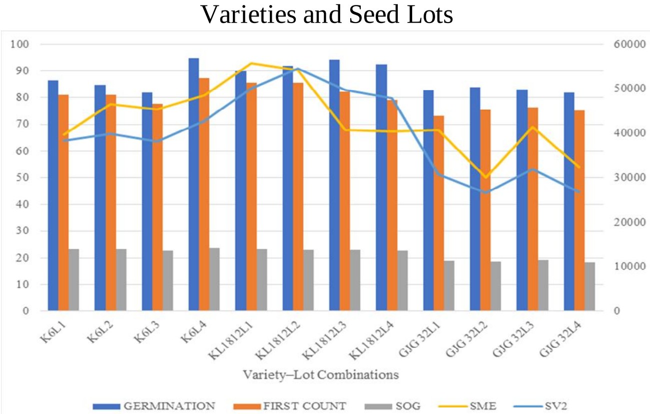

Fig. 2 : Physiological Vigour Characteristics of Groundnut Varieties and Seed Lots

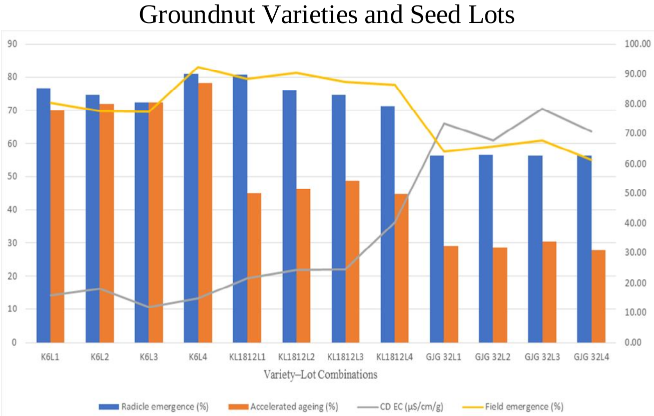

Fig. 3 : Stress Vigour Characteristics of Groundnut Varieties and Seed Lots

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