

Quantification of the seed vigour in maize (*Zea mays* L.) using a universal scale

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Maize (*Zea mays* L.) is the third most important cereal crop globally and plays a major role in ensuring food security, particularly in developing countries (Likhitha *et al.*, 2024). It is valued not only as human food and animal feed but also for industrial uses such as corn starch, corn oil, and baby corn production. In India, maize is grown on about 9.86 million hectares, with a production of 31.65 million tonnes and productivity of 32.65 q/ha (Sairam *et al.*, 2025). In Himachal Pradesh, it is a key *Kharif* crop cultivated on 0.262 million hectares, producing 0.711 million metric tonnes with productivity of 25.32 q/ha (Mridula *et al.*, 2025). Seed vigour refers to a seed's ability to germinate and establish healthy seedlings under diverse environmental conditions, ensuring rapid and uniform emergence and optimum plant stand (Hampton, 2002). Along with germination and viability, seed vigour represents an essential physiological component of seed quality that determines a seed lot's planting value. Vigorous seed leads to better establishment, improved stress tolerance, reduced pest and disease susceptibility, uniform growth, and ultimately higher yield. High-quality seed can increase crop yield by 15–20%, highlighting its importance in crop production (Dhiman *et al.*, 2026). Seed vigour is influenced by many factors such as genetics, environment, seed size, mother plant nutrition, and maturity at harvest, ageing, and pathogens (Ojo, 2000).

Since seed lots contain variation in vigour, vigour testing and correlation with field emergence are necessary to rank seed lots and select superior quality seeds (Golijan *et al.*, 2025). Therefore, the experiment was conducted to study the effect of variety and seed lot on maize seed quality parameters.

The research was conducted during 2021–2022 in the laboratory of the Department of Seed Science and Technology, College of Agriculture, CSKHPKV, Palampur (H.P.). Maize lots of two varieties, Bajaura Makka and Girija, each comprising five lots collected from different locations. For both varieties, Lot 1 was obtained from CSKHPKV Regional Station, Daulakuan (Sirmour, HP); Lot 2 from CSKHPKV Research Station, Berthin (Bilaspur, HP); Lot 3 from the Department of Seed Science and Technology, CSKHPKV, Palampur (HP); Lot 4 from Mr. Kashmir Singh, Village Darumka, PO Kachhera, Tehsil Jaisinghpur (Kangra, HP); and Lot 5 from Mr. Parvesh, Village Hatwas, PO Nagrota Bhagwan (Kangra, HP). Maize lots of two varieties, Bajaura Makka and Girija, each comprising five lots collected from different locations. For both varieties, Lot 1 was obtained from CSKHPKV Regional Station, Daulakuan (Sirmour, HP); Lot 2 from CSKHPKV Research Station, Berthin (Bilaspur, HP); Lot 3 from the Department of Seed Science and Technology, CSKHPKV, Palampur (HP); Lot 4 from Mr. Kashmir



Singh, Village Darumka, PO Kachhera, Tehsil Jaisinghpur (Kangra, HP); and Lot 5 from Mr. Parvesh, Village Hatwas, PO Nagrota Bhagwan (Kangra, HP). The experiment was laid out in a Completely Randomized Design (CRD) with four replications. A standard germination test was performed using 400 seeds per lot (4 replications of 100 seeds) following the ISTA between paper methods (BP). Seeds were incubated in a germinator at $25\pm 1^{\circ}\text{C}$ and 90% RH, and final germination was recorded on the 7th day (ISTA, 2022). Germination (%) was calculated based on normal seedlings. From the same test, time to 2 mm radicle emergence was recorded using 4 replication of 50 randomly selected seeds, and the mean value was expressed in hours. Germination factor (GF) was derived by dividing germination (%) by 100. Seedling vigour was assessed through seedling length (TSL, cm) and seedling dry weight (TSW, mg) using 10 normal seedlings per replication (Abdual-Baki & Anderson, 1973). Seedling factors (SF), germination based on seedling length factors (GSLF) and germination based on seedling dry weight factors (GSWF), and vigour indices (SVI-I and SVI-II) were computed using standard formulas. Field emergence was evaluated under field conditions (400 seeds per lot), and emergence (%) was recorded on the 20th day after sowing. Correlation of selected laboratory vigour parameters with field emergence was analyzed using the OPSTAT Program (Sheoran *et al.*, 1998).

The effect of maize variety, seed lot and their interaction on seed quality and vigour parameters is presented in Table 1 and Table 2 while correlation among traits is given in Table 3. Analysis of variance (ANOVA) revealed that all studied seed quality parameters, namely germination (%), 2 mm radicle emergence time (hrs.), GF, TSL, TSW, SF, GSLF, GSWF, SVI-I and SVI-II and field emergence (%) were significantly influenced by varieties, seed lots, and their interaction. Among varieties, V2 recorded the least time for 2 mm radicle emergence, indicating faster initiation of germination. However, V1 exhibited superior performance across most vigour-related parameters. It recorded significantly higher germination, GF, TSL, TSW, SF based on length (0.98), GSLF, SF based on seedling weight, GSWF, SVI-I, SVI-II and field emergence (Table 1). The significant varietal differences in vigour may be attributed to genetic variation among cultivars affecting physical and physiological seed traits (Powell, 2022). Cultivars differ in seed size, shape, boldness,

stored reserves, root system type, plant stature, nutrient and water uptake capacity, and resistance to pests and diseases. Varieties possessing advantageous traits (e.g., deeper root system, vigorous plant growth, greater photosynthetic foliage and better nutrient acquisition) produce more robust and bold seeds, leading to better field establishment and vigour. Genetic variability directly affects seed size, weight and density, and seed size is an important component of seed quality influencing crop performance (Adebisi, 2004; Adebisi *et al.*, 2011). Previous studies in crops like wheat and amaranthus also support this view, showing that larger seeds tend to possess higher physiological quality and produce more vigorous seedlings, with seed size positively correlated with vigour and emergence performance in several crops (Menaka and Balamurugan, 2008).

Seed lots also differed significantly for vigour traits (Table 1). L5 recorded the least radicle emergence time. In contrast, L3 produced the best overall performance for most traits. It recorded the highest germination, which was statistically at par with L4. Lot L3 also showed higher GF, TSL, TSW, GSLF, GSWF, SVI-I at par with L1, SVI-II and field emergence, which was at par with L4 and L1. Differences in vigour within and among seed lots may arise due to heterogeneity in seed development environments on the mother plant. Seeds in a lot originate from multiple plants grown under slightly different micro-environments, and even within a single plant, seeds differ in size and stored reserves. In addition, post-harvest handling, processing, and storage conditions may further contribute to variation in vigour, resulting in differences in seed performance. Komba *et al.* (2007) reported similar results in kale.

The interaction between variety and seed lot was significant for all key vigour parameters (Table 2), indicating that the performance of a variety depends on the seed lot source. The combination V2L3 recorded the lowest 2 mm radicle emergence time, at par with V2L1. For vigour and germination traits, V1L3 performed best, recording the highest germination, at par with V1L1 and V1L2. V1L3 also recorded the highest GF which was at par with V1L1, TSL, TSW which was at par with V1L1, SF based on length, GSLF at par with V1L1, SF based on weight, GSWF, VI-I which was at par with V1L1, and SVI-II which at at par with V1L1. However, the highest



Table 1. Effect of variety and seed lots on seed quality parameters in maize

Treatment	2 mm radical emergence (hrs.)	Germination (%)	Germination factor (GF)	Seedling length-TSL (cm)	Seedling weight-TSW (mg)	Seedling factor (SF)=TSL/highest TSL	Germination seedling factor (GSLF)	Seedling factor (SF)=TSW/highest TSW	Germination seedling factor (GSWF)	SVI-I (G% x SL)	SVI-II (G% x SDW)	Field emergence (%)
	1	2	3	4	5	6	7	8	9	10	11	12
Variety (V)												
V1	11.64	96.45 (79.24)	0.96	35.74	70.85	0.98	0.95	0.98	0.95	3446.95	6834.28	88.75 (70.40)
V2	10.62	92.35 (73.99)	0.92	31.66	63.72	0.88	0.81	0.88	0.82	2923.68	5885.22	83.50 (66.02)
SEm±	0.013	0.20	0.002	0.043	0.038	0.001	0.002	0.001	0.001	6.99	10.50	0.160
CD (P=0.05)	0.038	0.60	0.005	0.125	0.112	0.002	0.006	0.002	0.004	20.29	30.48	0.465
Seed lot (L)												
L ₁	11.56	94.25 (76.72)	0.94	33.70	67.76	0.94	0.88	0.94	0.89	3183.80	6399.85	86.25 (68.40)
L ₂	11.05	94.25 (76.38)	0.94	33.62	66.88	0.93	0.88	0.93	0.88	3173.83	6310.36	85.75 (67.89)
L ₃	11.05	95.25 (77.78)	0.95	34.00	67.98	0.94	0.90	0.94	0.90	3243.23	6483.80	86.88 (68.86)
L ₄	11.21	94.75 (76.75)	0.95	33.65	67.05	0.93	0.88	0.93	0.88	3188.72	6353.74	86.38 (68.33)
L ₅	10.78	93.50 (75.43)	0.94	33.50	66.78	0.93	0.87	0.93	0.87	3136.99	6250.99	85.38 (67.58)
SEm±	0.021	0.32	0.003	0.068	0.061	0.001	0.003	0.001	0.002	11.05	16.61	0.253
CD (P=0.05)	0.061	0.94	0.007	0.197	0.177	0.002	0.009	0.002	0.007	32.08	48.19	0.735

V1 - BajauraMakka; V2 - Girija; L₁ - Regional Station Daulakuan lot; L₂ - Research Station Berthin, Bilaspur lot; L₃ - Dept. of Seed Science & Technology lot; L₄ - Jaisinghpur, Kangra lot; L₅ - NagrotaBhagwan, Kangra lot; (GSLF) = TSL/highest TSL; (GSWF) = TSW/highest TSW. Figures in parenthesis are arcsine transformed value.



Table 2: Interaction effect of variety and seed lot on seed quality parameters in maize

Treatment	2 mm radical emergence (hrs.)	Germination (%)	Germination factor (GF)	Seedling length-TSL (cm)	Seedling weight-TSW (mg)	Seedling factor (SF)=TSL/highest TSL	Germination seedling factor (GSLF)	Seedling factor (SF)=TSW/highest TSW	Germination seedling factor (GSWF)	SVH (G% x SL)	SVI-II (G% x SDW)	Field emergence (%)
Interaction (VXL)												
V ₁ L ₁	12.38	97.50 (80.92)	0.98	36.02	71.88	0.99	0.97	0.99	0.97	3512.45	700782	90.00 (71.55)
V ₁ L ₂	11.55	96.50 (79.21)	0.96	35.70	70.15	0.97	0.95	0.97	0.94	3445.07	6769.48	88.50 (70.15)
V ₁ L ₃	11.58	97.50 (80.91)	0.98	36.10	72.05	1.00	0.97	1.00	0.98	3519.77	7024.88	89.75 (71.32)
V ₁ L ₄	11.95	95.00 (77.08)	0.95	35.25	70.05	0.97	0.92	0.97	0.92	3348.75	6654.75	87.50 (69.27)
V ₁ L ₅	10.72	95.75 (78.09)	0.96	35.60	70.12	0.97	0.94	0.97	0.93	3408.70	6714.48	88.00 (69.71)
V ₂ L ₁	10.75	91.00 (72.53)	0.91	31.38	63.65	0.88	0.79	0.88	0.80	2855.15	5791.88	82.50 (65.25)
V ₂ L ₂	10.55	92.00 (73.56)	0.92	31.55	63.60	0.88	0.80	0.88	0.81	2902.60	5851.25	83.00 (65.63)
V ₂ L ₃	10.52	93.00 (74.65)	0.93	31.90	63.90	0.89	0.82	0.89	0.82	2966.70	5942.72	84.00 (66.40)
V ₂ L ₄	11.48	94.50 (76.42)	0.94	32.05	64.05	0.90	0.84	0.89	0.84	3028.70	6052.72	85.25 (67.40)
V ₂ L ₅	10.82	91.25 (72.78)	0.91	31.40	63.42	0.88	0.79	0.88	0.80	2865.27	5787.50	82.75 (65.44)
SEM±	0.086	0.46	0.004	0.096	0.086	0.001	0.004	0.001	0.003	15.63	23.48	0.36
CD (P=0.05)	0.030	1.33	0.010	0.278	0.250	0.003	0.013	0.003	0.009	45.37	68.16	1.039

V₁ - Bajauramakka; V₂ - Girija; L₁ - Regional Station Daulakuan lot; L₂ - Research Station Berthin, Bilaspur lot; L₃ - Dept. of Seed Science & Technology lot; L₄ - Jaisinghpur, Kangra lot; L₅ - NagrotaBhagwan, Kangra lot; (GSLF) = TSL/highest TSL; (GSWF) = TSW/highest TSW. Figures in parenthesis are arcsine transformed value.

Table 3: Correlation between different seed quality parameters

Parameter	1	2	3	4	5	6
X1	1					
X2	0.9496*	1				
X3	0.9480*	0.9950*	1			
X4	0.9495*	1.0000*	0.9951*	1		
X5	0.9282*	0.9834*	0.9847*	0.9834*	1	
X6	0.9295*	0.9574*	0.9623*	0.9576*	0.9471*	1

X₁ = Germination (%); X₂ = Germination seedling length factor (GSLF); X₃ = Germination seedling dry weight factor (GSWF); X₄ = SVI-I; X₅ = SVI-II; X₆ = Field emergence (%). * Significant at P = 0.05 and P = 0.01; Critical value of 'r' at 5% = 0.3080 and at 1% = 0.3978



field emergence was recorded in V1L1, at par with V1L3. Shaheb *et al.* (2016) also shows that different varieties shows difference in seed quality parameters.

Correlation analysis (Table 3) showed that field emergence had strong and significant positive correlation with germination, GSLF, GSWF, SVI-I and SVI-II (0.9471) at both 5% and 1% significance levels. This confirms that laboratory-based vigour indices are reliable predictors of field establishment. Biradarpatil *et al.* (2023) reported similar results in groundnut and found strong correlation between field emergence and seed quality parameters. Overall, the study concludes that V1 and seed lot L3 and their interaction produced the best results for germination, seedling traits, vigour indices and field emergence. Since seed vigour determines rapid, uniform and robust seedling establishment, vigour quantification using multiple seed quality parameters can support effective seed selection and improve productivity. Future work should focus on elucidating physiological, biochemical and molecular mechanisms of vigour across genotypes and environments, including omics tools, stress-response evaluation, imaging-based assays, and multi-location field validation to strengthen predictive models for field performance.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Authors Contribution

KCD, RK, RKK – Conceptualization, Data Analysis, Revising of manuscript, AJ,KN, AT – Writing and revising of manuscript.

Ethical approval

The article doesn't contain any study involving ethical approval.

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No

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