RESEARCH ARTICLE Legume Research- An International Journal, Volume 46 Issue 11: 1467-1474 (November 2023)

# Prediction of Field Performance of Seed Lots of Groundnut (*Arachis hypogaea* L.) through Vigour Tests

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10.18805/LR-4458


## ABSTRACT

**Background:** Profitable farming indeed needs a seed which emerges and performs better under natural ecosystem. The inadequacy of seed germination test in predicting the field performance of a seed lot, as it is carried out under controlled laboratory conditions which may not meet in the field necessitates the development and standardization of tests in a way that would reflect the performance of seeds in the field through laboratory tests.

**Methods:** A laboratory based seed vigour tests were undertaken with 20 different seed lots of groundnut variety GPBD-4 having different vigour levels to predict the field performance. The correlation and regression analysis among the laboratory based seed vigour tests and field performance was analyzed.

**Conclusion:** The significance of lab vigour test on the field performance revealed that, electrical conductivity was highly negatively correlated to seed emergence, speed of emergence, plant population and pod yield with r = -0.885, -0.885, -0.843 and -0.845, respectively. Similarly, accelerated ageing was highly correlated to plant population (r = 0.864), plant height (0.737) and pod yield (r = 0.815). Whereas, the mean germination time calculated based on radicle emergence test contributed more than 80% to field performances and mean while, electrical conductivity influencing for 71.4% variation in the pod yield. Thus, hinting refinement and use of electric conductance, accelerated ageing and mean germination time tests towards efficient prediction of field performance of groundnut seed lots.


**Key words:** Accelerated ageing, Electrical conductivity, Mean germination time, Radicle emergence.

## INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is considered as the king of oil seed crops and is one of the important legume crops of the tropical and semi-arid countries, where it provides a major source of edible oil and vegetable protein. Groundnut seeds are more sensitive to storage conditions like high temperature; high seed moisture content and light exposure. Storing seeds after harvest till the next cropping season without impairing the quality is the challenging task for successful seed production as the lack of quality seed results in poor plant stand and low seedling vigour which is one of the major constraints for decreased productivity. This also owes to the low seed multiplication ratio in *kharif* and poor storability of *Rabi* / summer groundnut produce. Further, the *kharif* produce cannot be harvested and used for early *rabi* sowing which necessitates the use of *rabi* produce for sowing both during *kharif* and *rabi* seasons. However, storing seeds is an additional constraint in seedling establishment in the field. Such problems are generally due to high temperature prevailing during drying period and subsequent storage during *kharif* season causing rapid seed deterioration.

Seed vigour is a very important character in groundnut, which must be high during planting, so that the seed can resist many environmental factors affecting germination and field establishment. To test this, information obtained from germination test is inadequate and unreliable in prediction of field stand primarily due to the fact that the germination test in laboratory is carried out under very ideal conditions which seldom meet in the field (Agrawal, 1975). Due to this inadequacy, the legitimate concept of vigour was introduced and new tests for evaluating it were devised (Schuab *et al*., 2002). In this route, quite a large number of tests have been advocated, which can evaluate field performance of seed like accelerated ageing test for peas (Hampton and Tekrony, 1995), seed conductivity test for safflower (Khawari *et al*., 2009), cold test for corn (Noli *et al*., 2008), deterioration test and cool test for sugar beet (Hampton and Tekrony, 1995), which some of them are now internationally accepted. Radicle emergence test is one such identified vigour test, which give reliable results in crops like *Brassica* spp. (Matthews *et al*., 2011). However, not all clearly represent the field emergence, thus making it obligate to evaluate them in a way that would reflect the development of the seeds in the field through laboratory tests. Hence, there is a need to standardize responsive vigour tests which would help in determining the vigour of a particular seed lot that could be correlated with field performance.

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**How to cite this article:** Biradarpatil, N.K., Rana, S. and Patil, S.S. (2023). Prediction of Field Performance of Seed Lots of Groundnut (*Arachis hypogaea* L.) through Vigour Tests. Legume Research. 46(11): 1467-1474. doi: 10.18805/LR-4458.

**Submitted:** 09-07-2020 **Accepted:** 17-11-2020 **Online:** 02-02-2021

## MATERIALS AND METHODS

The present experiment was conducted in the Seed Quality Research Laboratory of National Seed Project, University of Agricultural Sciences, Dharwad.The experiment involved laboratory as well as field tests. In laboratory, twenty seed lots of GPBD-4 variety of groundnut having varied germination percentages were procured from Seed Unit, University of Agricultural Sciences, Dharwad and different vigour tests were carried out for validation of vigour test. For assessing field performance of the seed lots, the same twenty seed lots were sown in field adopting randomized complete lock design (RCBD) replicated thrice with a spacing of 30 × 10 cm to study the relationship of laboratory based vigour tests on field performance.

Observations recorded under laboratory conditions included germination percentage which was conducted by employing between paper method as prescribed by ISTA (Anonymous, 2012) in a germinator maintained at 25±2°C and the number of normal seedlings obtained was recorded on final count *i.e.,* 10th day and expressed in percentage.Ten normal seedlings in each replication were randomly selected for the measurement of root length and shoot length on the day of final count. The root length was measured from collar region to the tip of the primary root. The shoot length was measured from collar region to the point of attachment of cotyledons. The average of ten normal seedlings was expressed as root and shoot length in centimeters, respectively. The same ten seedlings were taken to determine seedling dry weightby drying in hot air oven at 70°C for 24 hours.

**Seedling vigour index (SVI)**

Seedling vigour index was calculated by adopting the formula suggested by Abdul-Baki and Anderson (1973):

Vigour index =
Germination (%) × [Root length (cm) + Shoot length (cm)]

**Electrical conductivity (EC) test**

Four replications of exactly five gram seeds were weighed and surface sterilized with 0.5% $HgCl_2$ for 30 seconds.The sterilized seeds were rinsed twice in distilled water and then soaked in 25 ml of distilled water and incubated at 25±1°C temperature for 24 hours (Presley, 1958). Electrical conductivity of seed leachate was measured in digital conductivity bridge (ELICO) with a cell constant 1.0 and the mean values were expressed in desi simons per meter ($dSm^{-1}$).

**Accelerated ageing (AA) test**

The pods were subjected to 42°C±1°C temperature and 95 per cent relative humidity (RH) by keeping them in monolayer on a wire gauge / mesh for a period of four days (Delouche and Bsakin, 1973). Accelerated aged seed samples were drawn after four days and subjected for germination test as described above.

**Radicle emergence (RE) test**

Seeds were kept for germination by employing paper towel method and number of seeds germinated everyday were counted considering 2 mm radicle size as germinated. The mean germination time (MGT) was then calculated using following formula given by Ellis and Roberts (1980).

$$MGT = \sum(nt) / \sum n$$

Where,
n = Number of seeds newly germinated at time 't' at 25°C.
t = Hours.

**Observation on field parameters**

**Field emergence (%)**

The seedlings with shoot of 1 cm and more visible above the ground were counted as emerged. The total seedlings emerged upto 15 days after sowing is considered and emergence percentage was calculated.

**Speed of emergence**

Number of normal seedlings emerged was counted everyday till the end of test period and was calculated using the formula suggested by Maguire (1962).

$$\text{Speed of emergence} = n_1/d_1+n_2/d_2+n_3/d_3+ \text{---}$$

Where,
n = Number of emerged seedlings.
d = Number of days.

**Growth and yield parameters**

The plant height was measuredfrom the base of the stemto top leaf at 30 days after sowingform five tagged plants and the same plants were used to record number of leaves. The number of plants survived in each plot was recorded before harvest for recording total plant population.The number of pods was counted separately on the selected tagged plants and the mean number of pods per plant was worked out. Number of pods per plot were weighed and pod yield per ha was computed.

**Statistical analysis**

The mean data obtained from the experimentation was statistically analysed and subjected to the Analysis of variance by adopting appropriate statistical methods as outlined by Panse and Sukhatme (1978) and Sundararaj *et al.* (1972). The critical differences were calculated at five percent and one percent level of probability for field and laboratory studies respectively wherever 'F' test was significant. The percentage data of germination were transformed into arc sine root transformation before analysis.

## RESULTS AND DISCUSSION

Sometimes fresh and revalidated seed lots tend to result in similar germination potential but eventually they differ in their vigour levels at laboratory as well as in the field scenario for which the germination test fails to differentiate it. Comparative laboratory and field experiments conducted by Odiemah (1995) and Adebisi *et al*. (2003) showed that under certain environmental conditions, there are close relationships between seed testing results and field emergence. To know this hidden yet yield influencing quality

of groundnut seeds, the relevant vigour tests are necessary for revealing this relatively narrow variation in the seed vigour/deterioration level of seed lots (Baalbaki *et al*., 2009).

In the present experiment, 20 seed lots with different germination levels are first checked for its laboratory based seed vigour test and ranked individually based on the results obtained for each vigour test. Significantly higher initial seed germination was recorded in lot 4 (96.50%) followed by lot 16 (91.50%) and the least value for germination was observed in lot 20 reporting 9.50 per cent germination (Table 1). Similarly, the seedling vigour was also significantly higher in lot 4 (2846) with lower mean germination time (36.86 h), whereas, least was recorded in lot 20 (190 and 44.67 h). This difference in the pattern of variation in seed germination and vigour is due to the age induced seed deterioration which causes drop in vigour followed by viability. Meanwhile, the similar trend of response with respect to seedling vigour as that of germination potential of the tested seed lots attributes to the components of seedling vigour test which includes the contribution of germination values with the seedling length measured at final count. The results of the study are in line with that of Manjunath (1993) who reported that high vigour seeds with higher initial germination had greater vigour index and significant linear reduction was observed in vigour index with decreased vigour levels in groundnut.

Interestingly, the lot 5 (96.50%) which had 6% of lesser germination than that of the lot 4 recorded significantly higher seed germination after accelerated ageing (67.50%) and lower electrical conductivity (0.063) than that of any other seed lots. The reduction in germination after accelerated ageing may be due to the stress conditions (high temperature and high relative humidity) which results in enhanced ageing conditions reducing the effects of internal factors that inhibit the germination process under normal condition (Ashraf and Habib, 2011). The seedling vigour gradually reduced with accelerated ageing. A number of metabolic processes accompany the loss of seed viability during ageing; hence, use of accelerated ageing in seed biology model experiments has been appropriately adopted for determining potential suitability of seeds for long term storage and better field performance and indirectly the vigour potential of seeds. Besides, Heslehurst (1988), suggested the use of electrical conductivity to evaluate the vigour of seeds as it gives high negative correlation with that of germination test, because the conductivity is related with the amount of ions leached into the solution, which in turn is directly associated with the integrity of the cellular membranes; badly structured membranes and damaged cells with which the process of seed deterioration and reduced vigour are associated. The loss of germination and vigour is negatively correlated with the electrolytic leaching, which increases with the decrease of the phospholipid content of the membrane (Lin, 1990). It was keen to note that, the lots with initial higher germination failed to express

**Table 1:** Relationship between germination with other laboratory vigour tests.

| Seed lots | Germination (%) | Seedling vigour index (SVI) | Electrical conductivity ($dSm^{-1}$) | Germination (%) accelerated ageing | Mean germination time (h) |
|---|---|---|---|---|---|
| $L_1$ | 62.00 (51.94)* | 1561 | 0.160 | 26.00 (30.64) | 37.76 |
| $L_2$ | 86.50 (68.45) | 2364 | 0.093 | 58.50 (49.88) | 37.07 |
| $L_3$ | 74.00 (59.33) | 2005 | 0.150 | 42.00 (40.38) | 38.60 |
| $L_4$ | 96.50 (79.33) | 2846 | 0.065 | 62.00 (51.93) | 36.86 |
| $L_5$ | 90.50 (72.14) | 2551 | 0.063 | 67.50 (55.23) | 37.21 |
| $L_6$ | 58.50 (49.90) | 1603 | 0.188 | 19.00 (25.82) | 41.74 |
| $L_7$ | 73.50 (59.00) | 1870 | 0.100 | 35.00 (36.25) | 40.06 |
| $L_8$ | 88.50 (70.19) | 2399 | 0.173 | 57.50 (49.30) | 39.72 |
| $L_9$ | 39.50 (38.92) | 1012 | 0.358 | 30.00 (33.19) | 41.23 |
| $L_{10}$ | 73.50 (59.03) | 1994 | 0.115 | 47.00 (43.26) | 39.23 |
| $L_{11}$ | 60.00 (50.76) | 1676 | 0.215 | 20.50 (26.89) | 41.03 |
| $L_{12}$ | 52.50 (46.42) | 1494 | 0.195 | 27.00 (31.27) | 40.27 |
| $L_{13}$ | 65.00 (53.73) | 1857 | 0.138 | 30.50 (33.48) | 38.04 |
| $L_{14}$ | 80.50 (63.81) | 2170 | 0.170 | 53.00 (46.70) | 37.97 |
| $L_{15}$ | 80.00 (63.50) | 2183 | 0.158 | 35.50 (36.55) | 37.62 |
| $L_{16}$ | 91.50 (73.05) | 2347 | 0.070 | 43.50 (41.25) | 38.87 |
| $L_{17}$ | 77.50 (61.69) | 2168 | 0.175 | 32.00 (34.43) | 39.06 |
| $L_{18}$ | 68.00 (55.58) | 1812 | 0.135 | 37.50 (37.74) | 39.04 |
| $L_{19}$ | 88.50 (70.19) | 2568 | 0.103 | 55.50 (48.14) | 37.77 |
| $L_{20}$ | 9.50 (17.92) | 190 | 0.430 | 0.01 (0.40) | 44.67 |
| Mean | 70.80 (58.24) | 1934 | 0.163 | 38.98 (37.64) | 39.19 |
| S.Em. ± | 1.08 | 58.68 | 0.004 | 0.63 | 0.42 |
| C.D. (0.01) | 4.07 | 220.77 | 0.015 | 2.37 | 1.59 |

*Figures in paranthesis indicates arcsine transformed values.

its vigour in other test. This confusion was clarified with the overall rankings obtained from the individual vigour test seed lot ranks, wherein, the lot 4, lot 5 and lot 2 were considered as the top three ranked high vigour seeds, whereas, lot 20 was ranked least (Table 2). The reliability of the laboratory based seed vigour test was simplified using correlation strategy, wherein, among the tests performed, germination after accelerated ageing and electrical conductivity gave higher correlation statistics to the seedling vigour index (r = 0.909 and 0.891, respectively). As rightly suggested, our present data of correlation also depicts the use of accelerated ageing and electrical conductivity as means of predicting vigour.

Mere laboratory based seed vigour test doesn't always mimic field performance. Therefore, simultaneously, the same 20 seed lots were tested for field performance (Table 3) wherein, the lot 16 was having significantly higher speed of emergence (9.77) and higher field emergence potential (89.26%), but were also on par with lot 4 (9.47 and 85.93%, respectively). Similarly, plant population (51.33) and plant height (7.27 cm) was significantly higher in lot 4. In compliance with the laboratory tests, the lot 20 recorded lowest with all the field based tests.

As predicted from the overall ranks (Table 2) obtained from laboratory oriented individual tests, the field performance tests also grouped lot 4, lot 5, lot 2, lot 19 and lot 16 under top 5 vigorous seeds. The significance of lab test on the field performance with the help of correlation and regression revealed that, electrical conductivity was highly negatively correlated to field emergence and speed of emergence with r = -0.885 and -0.885, respectively (Table 4). Here the electrical conductivity contributed to the extent of 78.2% to speed of emergence and 78.3% to field emergence (Table 5). Whereas, accelerated ageing contributed to only 63.4 % and 69.5%, respectively to speed of emergence and field emergence. Low vigour seed lots emerged poorly and more slowly. This was expected as Powell (1988); Tekrony and Egli (1977) have reported earlier that high vigour seed lots emerged better and faster than low vigour seed lots under stress conditions despite the fact that they had similar high laboratory germination percentages. Similar results were obtained from the present study as lot 8 and lot 19 both had similar germination of 88 percent however, lot 19 had higher speed of emergence (10.26) than lot 8 (Table 4).

Kapoor *et al*. (2010) opined that low seed vigour due to seed ageing was the result of biochemical changes. Ellis (1992) reported that seed vigour influences the early growth of plant both directly through physiological injury or necrotic lesions and indirectly through percentage emergence and emergence rate. Perry (1978); Kraak *et al*. (1984), Durrant *et al*. (1985) and Adebisi *et al*. (2003) had earlier reported strong correlations between standard germination and field emergence and seedling vigour index. This was probably due to the favourable environmental conditions encountered by seed during the period of field emergence and therefore standard germination may sometimes be taken as a

**Table 2:** Ranking of seed lots based on their performance in laboratory vigour tests.

| Seed lots | Germination (%) | Seedling vigour index (SVI) | Electrical conductivity ($dSm^{-1}$) | Germination (%) after accelerated ageing (AA) | Mean germination time(h) | Average of ranks | Ranks |
|---|---|---|---|---|---|---|---|
| $L_1$ | 15 | 17 | 12 | 17 | 5 | 12.75 | 15 |
| $L_2$ | 6 | 5 | 4 | 3 | 2 | 3.5 | 3 |
| $L_3$ | 10 | 10 | 10 | 9 | 9 | 9.5 | 10 |
| $L_4$ | 1 | 1 | 2 | 2 | 1 | 1.5 | 1 |
| $L_5$ | 3 | 3 | 1 | 1 | 3 | 2 | 2 |
| $L_6$ | 17 | 16 | 16 | 19 | 19 | 17.5 | 18 |
| $L_7$ | 12 | 12 | 5 | 12 | 15 | 11 | 12 |
| $L_8$ | 4.5 | 4 | 14 | 4 | 14 | 9 | 8 |
| $L_9$ | 19 | 19 | 19 | 15 | 18 | 17.75 | 19 |
| $L_{10}$ | 11 | 11 | 7 | 7 | 13 | 9.5 | 9 |
| $L_{11}$ | 16 | 15 | 18 | 18 | 17 | 17 | 17 |
| $L_{12}$ | 18 | 18 | 17 | 16 | 16 | 16.75 | 16 |
| $L_{13}$ | 14 | 13 | 9 | 14 | 8 | 11 | 13 |
| $L_{14}$ | 7 | 8 | 13 | 6 | 7 | 8.5 | 7 |
| $L_{15}$ | 8 | 7 | 11 | 11 | 4 | 8.25 | 6 |
| $L_{16}$ | 2 | 6 | 3 | 8 | 10 | 6.75 | 5 |
| $L_{17}$ | 9 | 9 | 15 | 13 | 12 | 12.25 | 14 |
| $L_{18}$ | 13 | 14 | 8 | 10 | 11 | 10.75 | 11 |
| $L_{19}$ | 4.5 | 2 | 6 | 5 | 6 | 4.77 | 4 |
| $L_{20}$ | 20 | 20 | 20 | 20 | 20 | 20 | 20 |

*Ranking of lots with the same average rank value is based on the accelerated aging test values.

predictor of seed vigour but not in all crops. The reduction in field emergence and plant population due to reduced seed vigour was also observed by many workers (Aswathaiah *et al.*, 1990; Alizag *et al.*, 1987). Correspondingly, experimental data represents germination after accelerated ageing was highly correlated to plant population (r =0.864) and plant height (r = 0.737) than that of any other tests performed. This indicates the potentiality of electrical conductivity and germination after accelerated ageing in determining the field performance of groundnut which can be possibly used in routine to determine the seed vigour.

Mean germination time *i.e.,* in simplest words, the radicle emergence was reported with higher negative correlation (r = -0.846) contributing for 71.5% variation to seedling vigour index among the laboratory based vigour tests. Mean time to germination increased in deteriorated seed lots in this study. It is in agreement with the findings of Khaje Hoseini *et al.* (2003) in soybean where deteriorated seeds took long time to germinate. The significant inverse regression between germination and MGT strongly suggests that natural ageing of these lots was the cause of differences in MGT. Similar results were found by Demir *et al.* (2008) in pepper seed lots. Matthews and Khajeh Hosseini (2007) pointed out that MGT can be thought of as the mean of the lag period, for all the seeds in a sample, between the time that the seeds start to imbibe and the first sign of germination (radicle protrusion) or physiological germination (2 mm radicle). In term of a lag period prompted the suggestion that the increase in MGT seen in deteriorated seeds could result from the need for a period of repair at the start of germination (Matthews and Khajeh Hosseini, 2007). The greater the seed deterioration, the longer the lag phase needed for repair before germination commences. In the present experiment, it is also observed that, MGT also gave higher negative correlation to the field emergence (r = -0.813) with having its influence to 66 per cent on field emergence which sheds the light of possibility of it using in evaluating groundnut seed's field performance as it is faster, reproducible, reliable and easy to test with minimum human error and equipment needed as compared to electrical conductivity and accelerated ageing tests.

Plant population per plot gave significant relation with varied vigour levels (Table 3). Among the seed lots, lot 8 has highest (55.67) plant population per plot. High positive correlation of plant population (r = 0.94) with that of laboratory vigour tests was found with seedling vigour index and also inferred that final plant population was higher in seed lots with higher vigour levels. Among the laboratory tests, the germination test contributes 87.7% variation in final plant population in field. Regression analysis of plant population per plot with field emergence showed a variation of 94.3%, as plant population per plot is influenced by field

**Table 3:** Effect of vigour levels onspeed of emergence, field emergence, plant population per plot and days to 50 per cent flowering of groundnut (GPBD-4) variety.

| Seeds lots | Speed of emergence | Field emergence (%) | Plant population per plot | Plant height 30 DAS (cm) | Number of leaves (30 DAS) | Number of pods per plant | Pod yield per hectare (kg) |
|---|---|---|---|---|---|---|---|
| $L_1$ | 5.07 | 44.44 | 25.00 | 4.49 | 25.33 | 60.13 | 2363 |
| $L_2$ | 8.25 | 76.30 | 47.67 | 6.73 | 26.53 | 37.20 | 3450 |
| $L_3$ | 7.50 | 72.96 | 44.33 | 6.63 | 23.40 | 46.27 | 4713 |
| $L_4$ | 9.47 | 85.93 | 51.33 | 7.27 | 26.07 | 57.95 | 5032 |
| $L_5$ | 9.03 | 87.04 | 51.00 | 5.87 | 24.47 | 55.53 | 4824 |
| $L_6$ | 5.13 | 45.93 | 33.67 | 4.63 | 24.67 | 37.42 | 3263 |
| $L_7$ | 8.57 | 67.52 | 45.67 | 6.73 | 24.47 | 46.07 | 4794 |
| $L_8$ | 9.04 | 80.74 | 55.67 | 5.97 | 23.47 | 46.30 | 4280 |
| $L_9$ | 2.61 | 26.30 | 20.67 | 5.13 | 24.27 | 55.47 | 2009 |
| $L_{10}$ | 7.51 | 67.04 | 42.67 | 6.10 | 26.93 | 63.73 | 3996 |
| $L_{11}$ | 4.76 | 48.89 | 31.67 | 5.50 | 27.73 | 67.80 | 3023 |
| $L_{12}$ | 6.45 | 61.48 | 40.67 | 6.07 | 26.73 | 59.48 | 3161 |
| $L_{13}$ | 7.38 | 64.44 | 38.67 | 6.17 | 20.07 | 46.67 | 3723 |
| $L_{14}$ | 8.57 | 77.41 | 45.33 | 6.17 | 21.47 | 52.80 | 4657 |
| $L_{15}$ | 8.30 | 80.74 | 49.67 | 5.97 | 25.13 | 42.18 | 4270 |
| $L_{16}$ | 9.77 | 89.26 | 48.00 | 6.77 | 26.47 | 46.80 | 4540 |
| $L_{17}$ | 9.32 | 73.33 | 44.33 | 5.83 | 25.00 | 48.33 | 4396 |
| $L_{18}$ | 7.59 | 64.81 | 39.00 | 5.13 | 22.67 | 53.68 | 3739 |
| $L_{19}$ | 10.26 | 84.44 | 48.67 | 5.57 | 24.53 | 42.87 | 4993 |
| $L_{20}$ | 0.40 | 7.26 | 7.00 | 3.50 | 19.53 | 38.62 | 581 |
| Mean | 7.25 | 65.31 | 40.53 | 5.81 | 24.45 | 50.26 | 3790 |
| S.Em. ± | 0.46 | 3.88 | 3.94 | 0.58 | 1.55 | 4.19 | 308 |
| C.D. (0.05) | 1.31 | 11.12 | 11.28 | 1.67 | 4.44 | 12.01 | 883 |

*NS- Non significant.

emergence. Similar results regarding the impact of vigour on number of plants per $m^2$ was observed by Taweekul *et al*. (1998) in field pea seeds, where, the use of low vigour seed lots reduced number of plants per $m^2$ by 33 to 50 per cent.

Plant height and number of leaves showed significant differences among the seed lots based on vigour levels at 30 DAS, wherein, lot 4 recorded significantly higher plant height (7.27 cm) and lot 10 was having significant higher number of leaves (26.93). The correlation between field emergence and plant height at 30 DAS was found to be 0.80. Regression analysis showed that among all the laboratory tests the highest variation in plant height at 30 DAS was depicted by germination test ($R^2$ = 0.585) followed by seedling vigour test ($R^2$ = 0.577). The initial differences in plant height varied among vigour levels; higher vigour lots are recorded with higher plant height, however its influence diminishes as the plants progress from the juvenile to the reproductive phase. According to Rodo and Marcos-Filho (2003), initial plant development during the first 56 days, as measured by plant height and dry matter accumulation, was affected by seed vigour mainly when differences on seed physiological potential became wider.

Number of pods per plant is significantly related to varying vigour level of seed lots (Table 3) with highest number of pods per plant recorded by lot 11 (67.80). The number of pod per plant had no significant correlation with laboratory measured traits so it can be concluded that the seed quality has no impact on pods number per plant (Sheidaei *et al.,* 2014).

Pod yield per ha significantly related to varying vigour level of seed lots. The highest pod yield per ha was found in lot 4 and lot 19 (5032 and 4993 kg, respectively), which earlier are considered to be vigorous based on field performance. Relying, high positive correlation (Table 4) was depicted by seedling vigour index (r = 0.908) among the other laboratory vigour tests. The regression analysisalso depicted seedling vigour index to contribute highest (82.4%) among the vigour tests for variation in yield per ha. There was a difference of 88.4 per cent in yield of highly vigorous (lot 4) and least vigorous (lot 20) seed lots. Similar decline in yield was observed among the varied vigorous seed lots, where poor stand establishment and growth of plants from seed lots having 92 per cent and 88 per cent seed germination led to yield loss by 23.7 per cent and 41.5 per cent, respectively (Golezani and Dalil, 2014). These results showed that production and cultivation of high vigour seeds are necessary to ensure satisfactory field performance. The yield parameter is contributed by two major factors *i.e.* firstly individual contribution, secondly through total number of plants present in the area. Regression analysis showed that, germination, seedling vigour index, electrical conductivity and accelerated ageing contribute to 82.3, 82.4, 71.4 and 58.9 per cent variation in pod yield per ha. Although vigorous seed lots yielded higher than non-vigorous seeds lots but some discrepancies are there among the lots

**Table 4:** Correlation between laboratory and field parameters.

| | Germination (%) | Seedling vigour index (SVI) | EC ($dSm^{-1}$) | G (%) after AA | MGT (hr) | Field emergence (%) | Speed of emergence | Final plant population | Plant height (30 DAS) | Yield /ha (kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| Germination (%) | 1 | | | | | | | | | |
| Seedling vigour Index (SVI) | 0.991** | 1 | | | | | | | | |
| Electrical conductivity ($dSm^{-1}$) | -0.893** | -0.891** | 1 | | | | | | | |
| Germination (%) after AA | 0.913** | 0.909** | -0.794** | 1 | | | | | | |
| Mean germination time (hr) | -0.836** | -0.846** | 0.822** | -0.834** | 1 | | | | | |
| Field emergence (%) | 0.952** | 0.957** | -0.885** | 0.865** | -0.813** | 1 | | | | |
| Speed of emergence | 0.934** | 0.941** | -0.885** | 0.834** | -0.786** | 0.977** | 1 | | | |
| Final plant population | 0.926** | 0.936** | -0.843** | 0.864** | -0.735** | 0.972** | 0.952* | 1 | | |
| Plant Height (30 DAS) | 0.770** | 0.760** | -0.728** | 0.737** | -0.653** | 0.800** | 0.766** | 0.810** | 1 | |
| Pod yield/ha (kg) | 0.896** | 0.908** | -0.845** | 0.815** | -0.717** | 0.935** | 0.944** | 0.927** | 0.785** | 1 |

**Correlation is significant at the 0.01 level of probability; *Correlation is significant at the 0.05 level of probability.

**Table 5:** Regression analysis between laboratory tests and field parameters.

| Laboratory tests→ | Germination (%) | | Seedling vigour index (SVI) | | Electrical conductivity (EC) | | Germination % after accelerated aging | | Mean germination time | |
|---|---|---|---|---|---|---|---|---|---|---|
| Field parameters↓ | $R^2$ | Regression equation | $R^2$ | Regression equation | $R^2$ | Regression equation | $R^2$ | Regression equation | $R^2$ | Regression equation |
| Speed of emergence | 0.896 | 0.116x-0.979 | 0.885 | 0.004x-0.443 | 0.782 | -24.47x+11.22 | 0.634 | 0.119x+2.608 | 0.617 | -1.035x+47.84 |
| Field emergence (%) | 0.922 | 0.998x-5.345 | 0.916 | 0.034x-0.919 | 0.783 | -207.3x+98.99 | 0.695 | 1.055x+24.17 | 0.660 | -9.07x+420.7 |
| Plant population/plot | 0.877 | 0.540x+2.250 | 0.876 | 0.018x+4.538 | 0.711 | -109.7x+58.36 | 0.682 | 0.580x+17.89 | 0.540 | -4.558x+219.1 |
| Plant height at 30 DAS | 0.585 | 0.033x+3.441 | 0.577 | 0.0001x+3.596 | 0.529 | -7.177x+6.977 | 0.473 | 0.036x+4382 | 0.426 | -0.306x+17.83 |
| Pod yield/ha | 0.823 | 0.005x+0.021 | 0.824 | 0.0001x+0.041 | 0.714 | -1.060x+0.551 | 0.589 | 0.005x+0.176 | 0.514 | -0.042x+2.060 |

regarding yield parameters (number of pods per plant). This might be attributed to the fact that in low vigorous seed lots the seeds which were weak were eliminated from the plot at early stage thus the field emergence (%) of such plots were less while those which were retained initially had low speed of emergence but after their establishment these lots had minimum competition for space and nutrition thus, were able to yield on par or at times even more than the vigorous lots. However, vigorous lots performed low in terms of pod per plant because of the higher plant population resulting in competition among the plants for space and nutrition. Similar results for yields were observed by Kalappa *et al.* (1989) who inferred that it was possible to realize normal crop yield to some extant through maintenance of optimum plant population by compensating the seed rate.

## CONCLUSION

In conclusion, the germination percentage is not a better indicator of the potentiality of seeds, but the vigour of seed plays the important role in assessing the field performance of the crops. The vigour tests conducted under study *viz*., electrical conductivity, accelerated ageing and radicle emergence on the chronology of strong correlation to predict field performance can be concluded with additional remarks on testing them under different laboratories, different field conditions and locations for its universal acceptance as to be used in routine prediction of field performance of a particular seed lot.

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