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CORRELATION AND REGRESSION ANALYSIS OF STANDARD GERMINATION AND FIELD EMERGENCE WITH VARIOUS VIABILITY AND VIGOUR TESTS IN TETRAPLOID AND DIPLOID COTTON

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ABSTRACT

Two seed lots, freshly harvested and aged seed (carryover seed) of two diploid (*Gossypium arboreum*) and two tetraploid (*Gossypium hirsutum*) cotton varieties were assessed for their viability and vigour parameters in laboratory at ICAR-CICR, Nagpur during 2018-19 and were correlated with standard germination and field emergence. Information regarding the relationship between laboratory seed vigour testing and seedling field emergence is very important to estimate seed performance after sowing and help producers adopt the best procedures to improve stand establishment.The correlation study revealed that the standard seed germination was positively correlated with vigour index, cold/cool germination, cool warm vigour index, methanol test, accelerated ageing test, pot germination and field emergence. Similarly, seedling emergence in the field was positively correlated with standard seed germination, vigour index, cold/cool germination, cool warm vigour index (CWVI), methanol test, accelerated ageing test and pot germination. Seedling length and critical root length showed poor association with seed quality indicating that the parameters are not good predictors of field emergence. Regression analysis advocated that cool/cold germination test, cool warm vigour index, accelerated ageing, methanol germination test and pot germination were more reliable predictors of standard germination based upon the values of coefficient of determination. Similarly, the pot germination, methanol germination test, accelerated ageing, cool/cold germination test, cool warm vigour index and standard germination were the most reliable predictors of field emergence.

(Key words: Cotton, correlation, regression, *aossypium,* seed viability and vigour)

INTRODUCTION

The issue of seed vigour is of central importance to agriculture and the seed industry, yet is still poorly understood and generally overlooked in academic research. Standard germination test is an indicator of seed quality, which can be used to predict the field emergence, if soil conditions are nearly ideal (Durrant and Gummerson, 1990). Testing of seed viability using different seed vigour tests is very significant, since vigour tests give results, which are often better correlated with the results of field germination under unfavourable environmental conditions, than the results obtained by application of standard laboratory germination test (Johanson and Wax, 1978).Understanding of the basis of variation in vigour and therefore, seed performance during the establishment of crops remains limited (Finch-Savage and Bassel, 2015).Therefore, Delouche (1967) and Heydecker (1969) have discussed the necessity of evaluating seed vigour in cotton seed.Vigour is an aspect of seed quality which controls field stand establishment ability and hence, vigour tests are required to obtain reliable assessments of field performance.To obtain more precise information about the quality of the seed lot, different vigour tests are used (Milocevic and Cirovic, 1994).Various studies have been conducted to study the morpho physiological traits and their correlation with yield by Chopde *et al*. (2012) in gladiolus; Ghewande *et al*. (2014) and Zode *et al*. (2000) in lathyrus; Raut *et al*. (2012) in mustard but very few studies have been conducted in cotton in relation to seed vigour parameters and their correlations with germination and field performances. Keeping these views in consideration, the present investigation was carried out to compare the applicability of various seed vigour tests like, standard germination test, methanol test, cold test, pot germination test, accelerated ageing, cool warm vigour index and other vigour indices in relation to cotton seedling establishment in the field.

MATERIALS AND METHODS

The present study comprised two each of tetraploid, (*Gossypium hirsutum*),Suraj and LRA-5166 and

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diploid (*Gossypiumarboreum*),PA-255 and AKA-8 varieties of cotton. Each variety having two seed lots, freshly harvested and aged seed (Carryover seed) procured from Division of Crop Improvement, ICAR-CICR, Nagpur used in the experiment. The experiment was conducted at laboratories and research farm of the ICAR-CICR, Nagpur during 2018-19 in complete randomised block design with three replications. Each seed lot of all the four varieties were used for various seed viability and vigour parameters in the laboratories, pot cultures and field experiments. The observations were recorded for standard seed germination (Anonymous, 2015), root, shoot, seedling lengths and vigour index (Abdul-Baki and Anderson, 1973), cold/cool germination test (Delouche and Baskin, 1970), methanol test (Hernandez, 1987), accelerated ageing test (Byrd and Delouche, 1971), cool warm vigour index (Metzer, 1987, Kerby *et al*., 1989), critical root length (Jensen, 2002), pot germination and field emergence.The replicated data recorded during the experiments conducted in laboratory, pots and field were processed and statistically analysed with the help of 'Statistical Software Package for Agricultural Research Workers' developed by Sheoran *et al.* (1998).

RESULTS AND DISCUSSION

The various vigour and viability parameters tested against the two seed lots of four cotton varieties were found significantly different. Correlation coefficient analysis was employed to find out the association among various seed viability and vigour parameters in different seed lots of diploid and tetraploid cotton varieties. It is evident from the Table 1 that all the 16 parameters were significantly correlated with standard seed germination and field emergence except critical root length.

The field emergence significantly correlated with standard seed germination at 4^{th}day (A1), standard seed germination at 7^{th}day (A2), total seedling length (A3); standard germination vigour Index at 4^{th}day (A4), standard 41 germination vigour index at 7^{th}day (A5), cold germination test (A6), cold test vigour index (A7); cool warm vigour index (CWVI) (A9). methanolgermination test (A10), accelerated ageing tests (A11-A14); pot germination (A15) and field emergence at 7^{th}day (A16). Similarly, all the vigour and viability parameters were significantly and positively correlated with standard germination test. The r values of respective parameters are indicated in the correlation matrix table (Table 1). The R square value was 0.8931 which is highly correlated with the characters under study with multiple R value of 0.9451.

Egli and Tekrony (1995 and 1996) found significant correlation between laboratory tests and seedling emergence in soybean.The relationship of standard germination test, seedling vigour classification, seedling length and tetrazolium staining to field emergence was evaluated in soybean by Roberts *et al*. (1979) and most of these laboratory tests were significantly correlated with field emergence. Jhamb (2008) in his correlation studies in cotton indicated that all the viability and vigour parameters were significantly and positively associated among themselves. Bajpai *et al*. (2015) demonstrated significant correlations with different vigour tests and field emergence in groundnut. Gregory *et al*. (1986) showed good correlations between the cool-warm vigour index (CWVI) test and initial stand establishment in cottonseed.

Standard germination showed positive significant association with standard germination vigour index at 4^{th}day (0.919**), standard germination vigour index at 7^{th}day (0.917**), cold germination test (0.987**), cold test vigour index (0.916**); cool warm vigour index (CWVI) (0.985**),methanol germination test (0.960**), accelerated ageing tests (0.948**; 0.942**; 0.981** and 0.971**) at 24, 48, 72, 96 hours, respectively; pot germination (0.957) and field emergence at 7th day (0.945**). Lee *et al.* (2000) observed that methanol concentration was linearly related to viability in soybean and so can be relevant as biochemical indicator of seed vigour. Significant and positive association of vigour tests with germination were also drawn by Freitas *et al*. (2000) and Lather *et al*. (1990) in cotton.An accelerated aging test showed that the aging seed is characterized by the loss of germination, reduced germination rate and poor seedling development in sunflower and soybean (Tatic *et al*., 2008).Sudharani and Padmasri (2014) carried out simple correlation studies and observed that final count of germination was suitable for assessing the seed vigour and accelerated aging for 48 hours for estimation of storage potential of cotton seed lots.

Comparatively poor association was observed with critical root length (0.726*) and seedling length (0.833*). Torres *et al.* (2004) reported that there was a close association between planting environmental conditions, seed physiological quality and seedling field emergence in soybean. The most accurate predictions were obtained for AA values e" 90%, when field emergence was higher than 80% ($r^2 = 0.90$**). Smith and Varvil (1984) for example found a good correlation between the percentage of germinated cotton seedlings with a root-hypocotyl longer than 38 mm after 7 days at 18°C in a paper roll test and field emergence under cool soil conditions.Jensen (2002) further added that CRL test correlated much better with field emergence percentage than a laboratory germination test and suggested a promising method for predicting field emergence in *Fagus sylvatica*.Seedlot characteristics such as seedling length, variation in seedling length, their subsequent seedling emergence, and seedling weight can also be correlated with percentage germination and speed of germination in carrot, leek, onion and cauliflower (Finch-Savage, 1986; Finch-Savage and McQuistan, 1988).

Field emergence was shown to be significantly associated with seed germination at 4th day (0.929**); standard seed germination at 7^{th}day (0.949**); standard germination vigour index at 4^{th}day (0.859**), standard germination vigour index at 7^{th}day (0.892**), cold germination test (0.965**), cold test vigour index (0.868**); cool warm vigour index (CWVI) (0.960**),methanol germination test (0.971**), accelerated ageing tests (0.889**, 0.972**, 0.959** and 0.970**) at 24, 48, 72, 96 hours, respectively; pot germination (0.998**) and field emergence at 4thday (0.993**) indicating that standard laboratory germination test can be used as a prediction criterion for field emergence.Madhu *et al.* (2014) reported that seedling establishment was positively correlated with standard germination, seedling length, seedling dry weight, vigour index I and vigour index II, accelerated ageing test and field emergence index in cotton. Bishnoi and Delouche (1980) reported significant correlation among vigour tests with seedling establishment in the field. Similar attempts have been made by Lovato *et al.* (2001) and suggested that accelerated ageing test is one of the most often used tests for vigour testing which can be well correlated with field emergence.

Comparatively, poor association was observed with seedling length (0.825*) and no association with critical root length (0.684^{NS}) with field emergence. However, Steiner *et al.* (1989) in wheat and Jensen (2002) in *Fagus sylvatica* confirmed that seedling radicle or critical root length was significantly correlated with vigour and field performance. They further advised that the large variation in root length between and within seed lots suggests that root length as measured in the CRL test is a very sensitive indicator of seed vigour and the performance of seeds during germination and establishment in the field.

The simultaneous variation of all the 10 parameters showed close relationship with standard germination by regression analysis. The estimated mean germination percentage obtained by various parameters *viz.*, field emergence (83.70%), seedling length (82.57 cm), vigour index (82.84), cold/cool germination test (84.81%), cool test vigour index (83.51), critical root length (83.55 cm), cool warm vigour index (85.30), methanol germination test (82.74%) accelerated ageing test (83.97%) and pot germination (83.79%) were at par with the value obtained by standard germination (83.0%). The actual mean was related to estimated mean for all the parameters as indicated in Table 2. Freitas *et al.* (2000) in their multiple regression analysis showed that the germination test was the most adequate for estimation of seedling emergence in the field, whereas the inclusion of the results from the germination tests at low temperature as well as of classification of the seedling vigour and electrical conductivity contributed to estimating the seedling emergence in the field. Similarly, Bolek (2006) screened 9 cotton genotypes for 5 different tests with cold and warm germination in cotton. The best test for predicting the field emergence was a combination of 30 and 18^{0}C tests (difference between 30 and 18^{0}C) alone.

The maximum value of R^2(coefficient of determination) was obtained for cool/cold germination test (R^2=0.975**), cool warm vigour index (0.972**), accelerated ageing test (0.944**), methanol germination test (0.922**) and pot germination (0.916**) as these tests were also found highly correlated with standard germination. Shakuntala *et al.* (2007) in their study indicated that methanol stress test (R=0.933**) and first count test (R=0.928**) were found to be more suitable to work out the vigour of chilli seeds while methanol stress test (R=0.961**) and germination index test (0.969**) were suitable to know the vigour of brinjal seeds. Dahiya *et al.* (2000) in sunflower and Madhu *et al.* (2014) in cotton employed regression analysis for finding the reliable predictor of standard germination with respect to seed viability and vigour parameters.

The estimated mean field emergence was obtained by various parameters *viz.*, standard germination (71.49%), seedling length (67.77 cm), vigour index (68.37), cold/cool germination test (72.60%), cool test vigour index (69.78), critical root length (69.84 cm), cool warm vigour index (73.64), methanol germination test (68.13%) accelerated ageing test (70.84%) and pot germination (70.53%) were at par with the value obtained by field emergence (68.70%) as indicated in Table 3. Pinki *et al.* (2018) observed that seed germination was positively correlated with vigour index- I and vigour index – II and with protein (%).Metzer(1987) and Kerby *et al.* (1989) suggested that the vigour index based on a combination of cool and standard germination test results can be used for predicting field emergence in cotton.

The maximum value of R^2(coefficient of determination) was obtained for pot germination (R^2=0.995**), methanol germination test (0.941**), accelerated ageing test (0.940**), cool/cold germination test (R^2=0.931**), cool warm vigour index (0.921**) and standard germination (0.901**) as these tests were also found highly correlated with field emergence. Tayal *et al.* (2006) and Madhu *et al.* (2014) also employed regression analysis for finding the reliable predictor of field emergence with respect to seed viability and vigour parameters in cotton.

The purpose of correlating the laboratory tests with the field parameters was to determine, if any indication of seed vigour expressed in the field under various environmental conditions can be assessed. Moreover, if emergence and establishment can be indicated by laboratory tests prior to planting, as the data indicated, a great benefit can be realized. Correlation studies indicated that all the viability and vigour parameters were (except seedling length and critical root length) significant and positively associated among themselves. Higher the values of vigour and viability parameters tested, better is the seed quality and vice-versa. Seedling length and critical root length showed poor association with seed quality indicating that the parameters are not good predictors of field emergence. Vigour parameters *viz.*, cool warm vigour index, accelerated ageing test, cold/cool germination test, methanol test, pot germination and vigour index were some of the important vigour tests found to be the most reliable predictors of standard seed germination or field emergence based upon the values of coefficient of determination.

Table 1. Correlation Coefficient Matrix Table for vigour and viability parameters of different seed lots of tetraploid and diploid cotton

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	1																
A2	0.961^{**}	1															
A3	0.775^{*}	0.833^{*}	1														
A4	0.840^{**}	0.919^{**}	0.850^{**}	1													
A5	0.861^{**}	0.917^{**}	0.983^{**}	0.905^{**}	1												
A6	0.970^{**}	0.987^{**}	0.850^{**}	0.879^{**}	0.922^{**}	1											
A7	0.867^{**}	0.916^{**}	0.923^{**}	0.931^{**}	0.962^{**}	0.906^{**}	1										
A8	0.634^{NS}	0.726^{*}	0.908^{**}	0.883^{**}	0.886^{**}	0.714^{*}	0.907^{**}	1									
A9	0.986^{**}	0.985^{**}	0.831^{*}	0.872^{**}	0.908^{**}	0.997^{**}	0.900^{**}	0.693^{NS}	1								
A10	0.938^{**}	0.960^{**}	0.830^{*}	0.808^{*}	0.901^{**}	0.974^{**}	0.856^{**}	0.629^{NS}	0.969^{**}	1							
A11	0.923^{**}	0.948^{**}	0.706^{NS}	0.803^{*}	0.805^{*}	0.958^{**}	0.826^{*}	0.602^{NS}	0.953^{**}	0.910^{**}	1						
A12	0.970^{**}	0.942^{**}	0.800^{*}	0.788^{*}	0.871^{**}	0.972^{**}	0.847^{**}	0.610^{NS}	0.978^{**}	0.977^{**}	0.908^{**}	1					
A13	0.973^{**}	0.981^{**}	0.848^{**}	0.864^{**}	0.917^{**}	0.999^{**}	0.893^{**}	0.700^{NS}	0.997^{**}	0.973^{**}	0.955^{**}	0.975^{**}	1				
A14	0.955^{**}	0.971^{**}	0.812^{*}	0.821^{*}	0.889^{**}	0.991^{**}	0.858^{**}	0.634^{NS}	0.986^{**}	0.991^{**}	0.953^{**}	0.981^{**}	0.990^{**}	1			
A15	0.935^{**}	0.957^{**}	0.835^{**}	0.885^{**}	0.903^{**}	0.965^{**}	0.884^{**}	0.708^{*}	0.962^{**}	0.965^{**}	0.883^{**}	0.966^{**}	0.958^{**}	0.964^{**}	1		
A16	0.898^{**}	0.945^{**}	0.824^{*}	0.859^{**}	0.891^{**}	0.956^{**}	0.872^{**}	0.696^{NS}	0.943^{**}	0.967^{**}	0.892^{**}	0.951^{**}	0.946^{**}	0.964^{**}	0.989^{**}	1	
A17	0.929^{**}	0.949^{**}	0.825^{*}	0.859^{**}	0.892^{**}	0.965^{**}	0.868^{**}	0.684^{NS}	0.960^{**}	0.971^{**}	0.889^{**}	0.972^{**}	0.959^{**}	0.970^{**}	0.998^{**}	0.993^{**}	1

*, ** Significant at P=0.05 and P=0.01levels, respectively.R-square value=0.8931; Multiple R-value=0.9451.

Note: A1=Standard Seed Germination at 4thday; A2=Standard Seed Germination at 7thday; A3=Standard Germination Seedling Length; A4=Std. Germination Vigour Index at 4thday; A5=Standard Germination Vigour Index at 7thday;A6=Cold/Cool Germination Test; A7=Cold/Cool Test Vigour Index; A8=Critical Root Length; A9=Cool Warm Vigour Index (CWVI); A10=Methanol GerminationTest; A11=Accelerated Ageing Test at 24 hrs.; A12=Accelerated Ageing at48 hours; A13=Accelerated Ageing at72 hours; A14=Accelerated Ageing at96 hours; A15=Pot Germination; A16=Field Emergence at 7th day and A17= Field Emergence at 14th day.

Table 2. Relationship between field emergence (%) and various vigour tests for seed quality assessment in different seed lots of cotton

Kind of test	Mean and Range		Correlation	Regression	R-square
	Actual	Estimated			
Final Standard					
Germination	82.3 (76.3-90.7)	71.49 (54.69-84.77)	0.95**	-104.7 + (2.089) x(76.3-90.7) *	0.9007
Seedling Length	22.0 (17.7-26.1)	67.77 (57.12-79.63)	0.83**	9.68 + (2.68) x(17.7-26.1) *	0.6794
Vigour Index					
(Std. Germination)	1837.4 (1349.4-2371.8)	68.37 (56.11-82.70)	0.89**	21.03 + (0.026) x(1349.4-2371.8) *	0.7950
Cold/Cool Germ. Test	41.1 (24.7-58.3)	72.60 (53.53-84.58)	0.97**	30.71 + (0.924) x(24.7-58.3) *	0.9307
Vigour Index (Cool Test)	356.4 (97.6-1224.3)	69.78 (57.45-105.89)	0.87**	53.25 + (0.043) x(97.6-1224.3) *	0.7518
Critical Root Length	4.8 (2.17-7.47)	69.84 (58.63-78.68)	0.68^{NS}	50.42 + (3.783) x(2.17-7.47)	0.4667
Cool Warm Vigour Index	114.1 (91.7-139.3)	73.64 (55.07-85.06)	0.96**	-2.70 + (0.63) x(91.7-139.3) *	0.9206
Methanol Germination					
Test	64.5 (53.3-76.7)	68.13 (54.76-84.24)	0.97**	-12.40 + (1.26) x(53.3-76.7) *	0.9411
Final Accelerated Ageing	24.9 (12.0-38.0)	70.84 (53.46-84.14)	0.97**	39.30 + (1.18) x(12.0-38.0) *	0.9403
Pot Germination	71.3 (54.7-85.7)	70.53 (51.45-83.69)	0.99**	-5.44 + (1.04) x(54.7-85.7) *	0.9953
Pooled Field Emergence	68.7 (51.0-83.7)	70.30	-	-	-

*Range in various parameters over which regression equation can be applied

**Significant at 1% level (P=0.01)

- Field emergence is the dependent parameter
- Figures in parentheses indicate range

Table 3. Relationship between standard germination (%) and vigour tests for seed quality assessment in different seed lots of cotton

Kind of test	Mean and Range		Correlation	Regression	R-square
	Actual	Estimated			
Field Emergence	68.7 (51.0-83.7)	83.70 (75.31-89.37)	0.95**	53.38 + (0.43) x(51.0-83.7) *	0.9007
Seedling Length	22.0 (17.7-26.1)	82.57 (77.72-88.02)	0.83**	56.00 + (1.227) x(17.7-26.1) *	0.6887
Vigour Index					
(Std. Germination)	1837.4 (1349.4-2371.8)	82.84 (76.93-89.20)	0.92**	60.74 + (0.012) x(1349.4-2371.8) *	0.8398
Cold/Cool Germ. Test	41.1 (24.7-58.3)	84.81 (75.95-90.40)	0.99**	65.333 + (0.43) x(24.7-58.3) *	0.9752
Vigour Index (Cool Test)	356.4 (97.6-1224.3)	83.51 (77.64-101.30)	0.92**	75.59 + (0.021) x(97.6-1224.3) *	0.8372
Critical Root Length	4.8 (2.17-7.47)	83.55 (78.14-87.79)	0.73^{NS}	74.19 + (1.82) x(2.17-7.47) *	0.5248
Cool Warm Vigour Index	114.1 (91.7-139.3)	85.30 (76.46-90.36)	0.99**	49.68 + (0.292) x(91.7-139.3) *	0.9716
Methanol Germination Test	64.5 (53.3-76.7)	82.74 (76.70-89.94)	0.96**	46.53 + (0.566) x(53.3-76.7) *	0.9219
Final Accelerated Ageing	24.9 (12.0-38.0)	83.97 (76.1-90.14)	0.97**	69.62 + (0.54) x(12.0-38.0) *	0.9443
Pot Germination	71.3 (54.7-85.7)	83.79 (75.49-89.53)	0.96**	50.71 + (0.453) x(54.7-85.7) *	0.9155
Pooled Standard Germination	83.0 (76.3-90.7)	83.56	-	-	-

*Range in various parameters over which regression equation can be applied

**Significant at 1% level (P=0.01)

- Field emergence is the dependent parameter
- Figures in parentheses indicate range

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