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Use of seed vigour tests to predict seedling emergence of carrot

Puneet K. Singh, V.K. Pandita*, B.S. Tomar and Rakesh Seth**
ICAR-Indian Agricultural Research Institute, Regional Station, Karnal 132001, Haryana

ABSTRACT

The present study was conducted to evaluate seed vigour tests to predict field emergence in carrot (*Daucus carota* L.). Eight commercial carrot seed lots were compared by standard germination, vigour index, germination at non-standard temperatures, accelerated ageing and saturated salt accelerated ageing tests. These vigour tests were able to assess vigour differences among different seed lots. The field emergence percentage ranged from 33.2 to 56.5 in carrot seed lots. The seedling emergence percentage of the carrot seed lots in the field was positively and significantly correlated with standard germination (r = 0.937*), germination at non-standard temperature of 15°C (r = 0.954***) and saturated salt accelerated ageing using NaCl - RH 75% (r = 0.952***). Determination coefficient (R^2) of carrot seed lots for germination at non-standard temperatures of 15°C and saturated salt accelerated ageing using NaCl (RH 75%) were found significant and explains 91 and 90% of variation in field emergence, respectively. The results suggest that non-standard temperature of 15°C and saturated salt accelerated ageing using NaCl (RH 75%) can be used to predict seedling emergence of carrot seed lots.**

Key words: *Daucus carota*, vigour tests, seedling emergence.

INTRODUCTION

The laboratory germination test provides information about the seedling emergence potential of seed lots under favourable conditions. The importance of seed vigour as a quality attribute has gained ground only recently as the germination potential did not reflect satisfactorily field emergence under varied environmental conditions. Since standard germination test usually overestimates field emergence under sub-optimal field conditions, there is a need for development of dependable seed vigour tests for different crops. Even though many vigour tests were proposed, only a few have attained acceptance by seed analysts and seed testing organizations. One test that has been accepted is the accelerating ageing (AA) test (Copeland and McDonald, 2). The AA test is one of the most acceptable vigour tests and was found to predict the emergence of large seeded agronomic crops. However, it has some limitations when it was used for small seeded vegetables due to rapid absorption of water by the small seeds during ageing. As a result of the above limitations, the standard AA test was modified by using saturated salt solutions instead of water (Jianhua and McDonald, 9). Since, the relative humidity of saturated salt solutions is lower than that of water (100%), smaller seeds may absorb water more slowly. Therefore, the SSAA could also be helpful in predicting emergence of small seeded vegetables under field conditions. Non-standard temperatures were found useful for predicting emergence of vegetable seedlings under non-favourable conditions. Non-standard temperatures are also used to identify vigour differences among seed lots with similar standard germination percentages. Seed companies use thermo-gradient tables with a range of temperatures for determining vegetable seed vigour (McDonald, 13). In this experiment different saturated salts, with a wide range of relative humidity and non-standard temperatures were used to predict the field emergence of carrot.

*Corresponding author's E-mail: vndpandita@yahoo.com
**Seed Production Unit, IARI, New Delhi

MATERIALS AND METHODS

Eight seed lots (A-H) of two carrot cultivars (Pusa Rudhira and Pusa Asita) produced during winter 2009-10 were collected from different public and private agencies. The seed lots were hermetically sealed in aluminium foil and stored at room temperature till the start of experiment. Standard seed germination was determined as per ISTA (8). Four replications each of 25 × 4 seeds were placed in petri dish on moist blotter paper and incubated in walk-in-germinator maintained at 15°, 25° and 30°C. Germination percentage was calculated based on number of normal seedlings on final count.

High speed of germination is an indication of vigorous seed lot. Numbers of germinated seeds were counted daily from the first day and the cumulative index was made by the formula suggested by Maguire (10). Seedling vigour indices were calculated following formula suggested by Abdul Baki and Anderson (1). Four different saturated salt solutions, producing different relative humidities (water RH 100%, NaCl RH 75%, $Mg(NO_3)_2$ RH 53% and $CaCl_2$ RH 29%) were used for accelerated aging. The saturated salt solutions were prepared by dissolving individual salt in distilled water and further adding the same salt till saturation point was achieved. The accelerated ageing test was conducted according to the procedure described by Hampton and TeKrony (7). A small quantity of seed was drawn from each seed lot and spread out in thin layer in nylon net bag. These were then placed in ageing boxes and were kept in an incubator at 41°C for 72 h. For accelerated ageing test, distilled water was placed in ageing boxes, whereas for SSAA test respective saturated salt solutions were used. After the completion of ageing duration, seeds were tested for moisture content and standard germination. A seed which produces an identifiable seedling regardless of their size were counted as germinated and the per cent germination after accelerated ageing was calculated. Seeds of eight lots of carrot were sown under Delhi conditions at Division of Seed Science and Technology, IARI fields in October, 2010 and the emerged seedlings were counted daily until emergence is ceased. From the daily counts data final emergence percentage was recorded. Mean emergence time (MET) was calculated according to Ellis and Roberts (4).

The data from laboratory experiments were analysed by adopting complete randomized design (CRD). Statistical analysis was carried out using Statistical Package for Social Sciences (SPSS). Data were subjected to analysis of variance and means were compared. All the replicated data were subjected to Duncan's multiple range test. Correlation coefficients (r) of various vigour tests with field emergence were calculated. The significance of the fitted model was assessed by R^2 (Co-efficient of determination).

RESULTS AND DISCUSSION

The germination percentage varied significantly among the different vigour level seed lots. Seed lot B (82.0%) recorded maximum standard germination and in general, all the seed lots of showed higher than the prescribed minimum standard for germination (Table 1). Das Gupta and Austenson (3) also concluded that the germination test could be supplemented with other tests to more reliably assess expected crop performance. Seed lot C (27.02) recorded the maximum speed of germination, whereas, seed lot F (13.96) showed significantly lower speed of germination. Yadav and Dhankar (15) reported that vigour indices were positively and significantly correlated with standard germination, seedling length and seedling dry weight and negatively correlated with electrical conductivity in okra. There were significant differences between seed lots for vigour index and germination at non-standard temperatures. The vigour of lots D and H was lower than that of the other lots although the ranking was not always same between two vigour indices. The field emergence percentage and mean emergence time differed significantly among different seed lots. The maximum field emergence was recorded in seed lot B (56.5%) followed by seed lot C (54.2%). The minimum field emergence was recorded with seed lot F (35%) and was at par with seed lot H (35.0%) and G (36.7%).

There were significant differences in germination between seed lots at each of the non-standard temperatures of 15°, 25° and 30°C (Table 2). Seed lot F and H showed lower germination than other seed lots. The range of temperatures at which the maximum germination percentage occurs, differs among crops and with seed quality. In general, temperature range becomes narrower as a seed lot deteriorates (Ellis

Table 1. Germination, emergence and vigour of 8 carrot seed lots.

Seed lot	Germination (%)	Speed of germination	Vigour index-I	Vigour index-II	Field emergence (%)	Mean emergence time
A	68.0cd	22.86b	677.94c	0.976cd	39.7cd	3.08ab
B	82.0a	24.44b	754.03ab	1.118b	56.5a	2.67b
C	81.3a	27.02a	779.27a	1.092b	54.2a	2.77ab
D	72.6bc	23.43b	592.04d	0.903d	45.7b	3.11ab
E	76.0ab	23.78b	686.38bc	1.009bcd	43.5bc	2.56b
F	61.6de	13.96d	501.38e	1.053bc	33.2e	3.45a
G	70.3bc	14.42d	383.00abc	1.29a	36.7de	2.82ab
H	60.6e	17.27c	513.68e	0.97cd	35.0e	2.73ab
CD (P = 0.05)	6.83	2.16	68.51	0.10	4.14	0.68

Means followed by the same letters are not significantly different.
Separation by Duncan's Multiple Range test at 5% level of significance.

Table 2. Seed vigour of 8 carrot seed lots assessed by germination at non-standard temperatures, accelerated aging and saturated salt accelerated ageing tests.

Seed lot	Germination at non-standard temperatures			AA test	Saturated salt accelerated ageing test		
	15°C	25°C	30°C	RH 100%	RH 75%	RH 53%	RH 29%
A	65.33c	68.66d	68.00cd	40.6c	49.3c	62.6b	66.3cd
B	81.33a	82.00a	82.66a	60.6a	77.3a	75.6a	77.3a
C	81.33a	78.00ab	83.33a	54.6ab	76.0ab	75.3a	76.3ab
D	65.33c	74.00bc	74.66b	46.0bc	69.3ab	68.6ab	73.3abc
E	73.33b	70.66cd	72.66bc	44.00c	68.0b	64.0b	68.6bcd
F	54.66e	56.00f	57.33e	38.6c	38.6d	63.3b	66.6cd
G	60.66cd	70.00cd	75.33b	46.0bc	46.6cd	58.6b	65.3cd
H	57.33de	63.66e	63.00de	47.33bc	42.66cd	59.33b	61.33d
CD (P = 0.05)	5.10	4.57	5.83	9.18	8.35	9.42	7.54

Means followed by the same letters are not significantly different.
Separation by Duncan's Multiple Range test at 5% level of significance.

and Roberts, 5). Germination percentages at non-standard temperatures and different ageing conditions can be used to separate seed lots according to their vigour levels (Fessehazion *et al*., 6). Germination percent after accelerated ageing of two different carrot cultivars comprising of 8 seed lots differed significantly (Table 2). The results of accelerated ageing test showed that seed lot B at RH 100% was able to retain maximum germination (60.6%) but seed lot F showed significantly low germination of 38.6%. The overall germination of different seed lots was lower after accelerating ageing (RH 100%) as compared to that of saturated salt accelerated ageing (SSAA) test using different saturated salts. This was due to high incidence of fungal infection encountered during AA at RH 100%. Seed lot B maintained higher germination of 77.3% after saturated salt accelerated ageing using NaCl (RH 75%), while seed lot F showed maximum deterioration in germination. Seed lot B also maintained higher germination after saturated salt accelerated ageing at RH 53 and 29%. Seed lot G showed significantly lower germination values at RH 53% (58.6%) and RH 29% (65.3%). Panobianco and Marcos-Filho (14) reported efficient use of the standard accelerated ageing test (41°C and 72 h) and saturated salt test using NaCl (RH 75%) for detection vigour difference among seed lots of tomato.

The relationship between various vigour tests results and field emergence of eight seed lots of two carrot varieties was studied by determining simple correlation co-efficient. In the present study the field emergence ranged from 56.5 to 33.2%. The correlation co-efficient (r) between field emergence and the vigour tests results were ranging from 0.041 to 0.954^{***} (Table 3). However, certain vigour tests had shown significant correlation with field emergence ranging from 0.729^{*} to 0.954^{***}.The correlation between standard germination and field emergence was significant ($r = 0.937^{***}$) at 0.01% significant level. The results of vigour indices, *viz.,* vigour index I ($r = 0.729^{*}$) was significant but vigour index II (r=0.041) was non-significant with field emergence. The correlation co-efficient (r) between field emergence and germination at non-standard temperature were ranging from 0.886^{**} (30°C) to 0.954^{***} (15°C). The results indicate that germination at non- standard temperature of 15°C is a better indicator of carrot seedling emergence in the field and can be successfully used to predict seedling emergence. Germination after accelerated ageing showed significant correlation with field emergence. It ranged from $r = 0.848^{**}$ (at 100% RH) to $r = 0.952^{***}$ (73% RH). Saturated salt accelerated ageing test using NaCl (RH 73%) correlated better with field emergence in carrot as compared to accelerated ageing test. McDonald (12) reported that SSAA test was found to reduce the rate of water absorption of small seeds and it was reproducible among laboratories applying vigour tests, which is one of the aims of a vigour test.

The regression analysis or Coefficient of determination (R^2) was analysed for 8 seed lots of two carrot varieties. The R^2 values of various vigour tests with field emergence ranged from 0.001 to 0.911 (Table 3). The coefficient of determination for standard germination ($R^2 = 0.86^{**}$) was found to be significant and it showed linear relationship with field emergence. It also showed that standard germination test contributed to 86% of the variation in the field emergence. Only 53% ($R^2 = 0.53$) and 0.1% ($R^2 = 0.001$) of the variation in field

Table 3. Comparison of independent variables against field emergence in carrot seed lots.

Vigour test		Correlation coefficient	Regression equation	R^2	P-value
Standard germination		0.937***	Y = 0.9341x – 23.533	0.862	**
Germination at non-standard temperatures	15°C	0.954***	Y = 0.8039x – 11.099	0.911	***
	25°C	0.923**	Y = 0.9855x – 26.258	0.853	**
	30°C	0.886**	Y = 0.8489x – 18.128	0.785	**
Mean germination time		0.634	Y = -8.0691x + 75.592	0.403	
Speed of germination		0.851**	Y = 1.4889x + 11.979	0.725	***
Vigour Index I		0.729*	Y = 0.0596x + 4.1703	0.532	***
Vigour Index II		0.041	Y = 3.033x + 36.904	0.001	
Saturated salt accelerated ageing	100% RH	0.848**	Y = 1.0165x – 4.9322	0.719	**
	75% RH	0.952***	Y = 0.5236x + 12.465	0.906	***
	53% RH	0.939***	Y = 1.2265x – 37.797	0.882	**
	29% RH	0.935***	Y = 1.4284x – 56.054	0.876	**

Significance level: $^{**}P < 0.01$, $^{***}P < 0.001$

emergence could be explained by Vigour Index I and II, respectively. The regression analysis for germination at non-standard temperatures was also estimated. The regression analysis for germination at 15°C temperature (0.91***) was significant. It also showed that non-standard germination test at 15°C contributed to 91% of the variation in the field emergence (Fig. 1). The regression analysis for germination at 25°C temperature (0.85**) was also significant. It showed that non-standard germination test at 25°C contributed to 85% of the variation in the field emergence. The regression analysis for mean germination time (R^2 = 0.40) was non-significant and showed that 40% of the variation in field emergence could be explained by the mean germination time test.

The regression analysis for accelerated ageing test (R^2 = 0.71*) and SSAA test at 75% RH (R^2 = 0.90**) were a found to be significant and explained 71 and 90% of the variation in field emergence by these two tests, respectively (Fig. 1). The regression analysis for saturated salt accelerated ageing test at 53% RH (R^2 = 0.88**) was also found to be significant. It explains that 88% of the variation in field emergence could be explained by SSAA test at 53% RH. The regression analysis for saturated salt accelerated ageing test at 29% RH (R^2 = 0.87**) was also found to be significant. It explains that 87% of the variation in field emergence could be explained by SSAA test at 29% RH. Mavi and Demir (11) also reported that germination after AA test can be related with emergence under stressed conditions in melon seeds.

The results suggest that non-standard temperatures of 15°C and saturated salt accelerated ageing using NaCl (RH75%) can be used to predict seedling emergence of carrot seed lots in the field.

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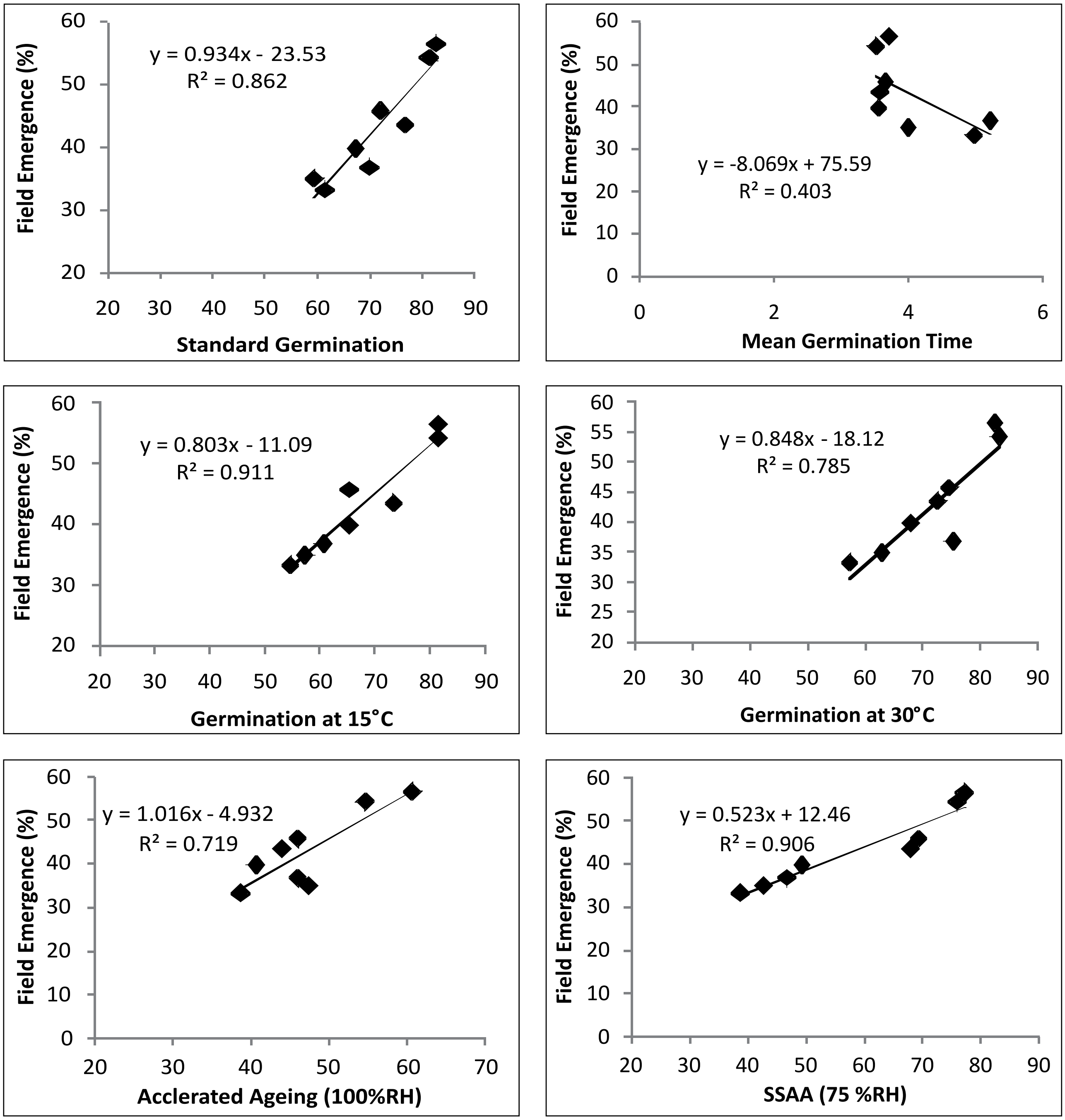

Fig. 1. Relationship between field emergence and standard germination, mean germination time, germination at 15°C, germination at 30°C, accelerated ageing, saturated salt accelerated ageing of eight carrot seed lots.

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