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Seed vigour tests for predicting field emergence of maize under severe conditions

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ABSTRACT

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With 40 to 50 different seed vigour tests available, appropriate procedures for choosing the best single test or combination of tests are necessary. The objective of this study was to select the best predictors of seedling emergence of maize (Zea mays L.) under severe conditions. Thirteen vigour tests and various field emergence trials were performed on six inbred lines and two commercial hybrids. The best single predictors of field emergence were identified by calculating simple correlation coefficients. The calculation of the geometric mean of the results of several vigour tests is a method for utilising multiple tests that are correlated. Taking all this into account, the tests which best predict seedling emergence were germination percentage in a saline solution at an osmotic potential (O.P.) of -2 bars, germination percentage at 10°C related to the control, and germination percentage in a saline solution at an O.P. of -6 bars.

INTRODUCTION

Some 40 to 50 laboratory test procedures have been proposed for measuring seed and seedling vigour of agronomic and horticultural crops. Many of these tests are described in the Seed Vigor Testing Handbook of the International Seed Testing Association (Perry, 1981). Most of them are based on one of the following criteria: germination and seedling growth characteristics, germination under stress conditions, survival under stress conditions, physical parameters, biochemical characteristics, and degree of mechanical damage.

Vigour tests are commonly evaluated according to their ability to predict some aspects of potential seed performance, particularly seedling growth rate, seedling emergence in the field, plant uniformity, and seed storability. Although vigour tests are normally designed to measure aspects of seed deterioration, attempts are sometimes made to employ the same tests to evaluate genetic differences in seed performance (Perry, 1970; Ching et al., 1977; Johnson and Wax, 1978; Burris and Navratil, 1979; Briggs and Horak, 1980; Wayne Smith and Varvil, 1984; Durrant et al., 1985; Martin et al., 1988).

With this array of possible vigour tests available, appropriate procedures for choosing the best single or multiple predictors of seed performance are necessary. Correlation coefficients are commonly used to indicate which tests have the closest relationship with seed performance under field conditions (De Tempe, 1963; Edje and Burris, 1970; Perry, 1970; Abdullahi and Vanderlip, 1972; Gill and Delouche, 1973; Tekrony and Egli, 1977; Johnson and Wax, 1978; Burris and Navratil, 1979; Yaklich and Kulik, 1979; Martin et al., 1988; Pandey, 1988).

In this research, we use simple correlation coefficients and the geometric mean of several co-linear variables that were good single predictors of seedling emergence (Steiner et al., 1989). The database was obtained from 13 vigour tests, variations, and field emergence of six inbred lines and two commercial hybrids, the latter used as checks.

MATERIALS AND METHODS

Genotypes

Genotypes of high, medium, and low field emergence response in Spain, two each, determined by the Estación Experimental de Aula Dei (EEAD) germplasm bank data, were utilized. High: CM105 and W64A. Medium: EZ7o2 and EZ18o2. Low: B14dec (decussate) and EZ19o2. The o2 genotypes were segregating for this gene. Seed was produced in the year 1987 in Zaragoza (Spain), and stored at 4°C. The seed was treated with 48% Maneb and 2% Lindano, except for gravel emergence, where substrate was sterilized, and in conductivity determinations. The reason for treating the seed was that, when it was not made, there was high fungi contamination and little germination. For the field trials, the seed was treated with the insecticide-nematicide "Curaterr". Two commercial hybrids were used as checks: INRA-260 (check 1) and P-3183 (check 2), except for the conductivity test.

Emergence trials

Emergence trials were conducted at the EEAD near Zaragoza in May 1988 , October 1988 , and April 1989 . The soil is a heavy, Haplic Calcisol, with an EC (1/5) of 0.22 dS/m. One hundred and eight seeds per plot were planted with a pneumatic driller at a depth of 5 cm in 5 m rows. Plots were of four rows separated 75 cm, in a randomised complete block design with three replications in May and October. In April there were three trials, sown in

April 14, April 21, and April 28 respectively, with only one replication. Final percentage of emergence (E%) and the emergence index (EI) (Czabator, 1962) were calculated. This index is the mean days from sowing to total emergence, and reflects emergence speed and completeness:

$$EI = \Sigma(d_i \times n_i)/n.$$

where d_i is the number of day after planting when emergence is evaluated; n_i is the number of seedlings emerged since the last evaluation; n. is the total number of seedlings emerged at the end of the test period.

This index reflects seed vigour, whereas percent emergence accounts for seed vigour plus viability. That is the reason for correlating the emergence index to correlate with the vigour tests.

Viability and vigour tests

Genotypes were subjected to 13 vigour tests, plus controls, plus variations; in total 47 tests as follows:

a) Germination "per se"

Germination percentages (GERM) were performed between blotters at 20°C for seven days in distilled water (AOSA, 1981 cited by Steiner et al. 1989).

b) PEG

Germination and first leaf development in polyethylene glycol (PEG) solutions as drought simulators were evaluated in percentage at O.P. of 0, -1, -2, -4, and -6 bars, using distilled water as a dissolvent (PEG/DW). PEG concentrations were calculated after Michel and Kaufmann (1973). Seeds were sown in sterile filter paper over a 5 mm thick sheath of polyurethane foam soaked in the PEG solution, and placed in plastic trays of 48.5 cm x 33.5 cm x 8 cm. Trays were then covered with a PVC film to prevent evaporation and put in the dark at 25 ± 1°C, in a similar way as described by Young et al. (1968). Evaluation was made 15 days after sowing. We observed in previous trials with commercial hybrids, that there was no first leaf development from -8 b on. To be sure that there is no effect of lack of oligoelements, we also carried out this experiment at an O.P. of -0.5 and -6 b, using well water of an electrical conductivity (EC) of 1.6 dS/m, as a dissolvent (PEG/WW).

c) Salinity

Germination and first leaf development in saline solutions (SALT) were evaluated in percentage at an EC of 5.6 and 16.7 dS/m, corresponding to an O.P. of -2 and -6 b, respectively. The test was carried out as with PEG/DW (Young et al., 1968; Martínez-Cob, 1985). The saline solution consisted of NaCl and $CaCl_2$ in a 1:1 weight proportion. Concentrations were calculated following Ayers and Westcot (1976). Evaluation was made 30 days after sowing, to give time enough to grow in spite of the possible toxic ionic effect.

d) Low temperature

Germination percentage at 10 ± 1°C (LT) was evaluated 12 days after seeding, using distilled water and polyurethane foam in trays as before. In previous trials with commercial hybrid seed,

we observed that germination at 5 and 8°C were less differentiating.

In GERM, PEG, SALT, and LT, we considered germinated seeds where the radicle had at least the length of the seed diameter. 275 ml of solution were applied to each tray. Two replications with 100 seeds per genotype were sowed in GERM. In PEG, SALT, and LT, three replications with 25 seeds per genotype and replication were sowed; the experiments were carried out following a split-plot design, with treatments as main plots and genotypes as subplots; for each treatment, one tray was one replication and block, within which genotypes were randomised; the control was the tray with O.P. = 0, cited in paragraph b.

e) Gravel emergence

Gravel emergence (GE) was evaluated using 16.5 cm plastic pots of 15.5 cm height. A plastic bag was used to prevent water loss. The pots were filled with 1200 cc peat, pressed down to 5 cm thickness, and levelled. 20 seeds were placed on the surface, without touching the inside of the pot. The seeds were then covered by a two centimetres thick layer of sand, allowing the hypocotyl to penetrate easily. These pots were used as controls. In order to simulate crusting, we added 7 cm of gravel. In an earlier trial with commercial hybrids, we tested gravels of different diameters: 2-4, 4-6, 6-8, and 8-10 mm, and found no significant differences. We thus conducted the experiment with 2-4 mm ϕ gravel. All pots were covered with a PVC film to prevent evaporation, which was removed when the first seedling emerged. The experiment was carried out in the dark at 20 ± 1°C. Before use the gravel and sand were autoclaved for two hours at 120°C. Evaluation of percentage of emerged seedlings was made 10 and 14 days after seeding. Pots were arranged in a randomised complete block design with three replications. The method is a modification of Ader's test (Perry, 1981).

f) Seedling growth

For root length, shoot length, seedling fresh weight, root weight, and shoot weight determinations, three replications of ten seeds were planted in single rows in rolled towels that were placed upright at 20°C for seven days. After measuring the shoot and main root of each normal seedling, the caryopses were removed and the seedling fresh weight, root weight, and shoot weight determined. The method is derived from Perry's 1981 seedling growth test.

g) Conductivity

Conductivity (C) of seed leachates, in microSiemens per centimeter per gram, was determined in three replications of 30 seeds after soaking in 150 ml distilled water at 20°C for 24 h. The method is similar to Mattews and Powell's (Perry, 1981). We did not use commercial seed because it was treated, and instead used hybrids CM105 x W64A (check 1) and EZ18o2 x EZ7o2 (check 2).

Statistical analysis

Statistical analyses were performed with the SPSS program (Norusis, 1986), after Bliss' transformation of percentages (Snedecor and Cochran, 1967), in order to have a normal distribution. Analyses of variance, Duncan's multiple range tests, and

correlations were calculated.

RESULTS AND DISCUSSION

Field emergence

These experiments were carried out to find differences in seed vigour under severe conditions that could be used as a check for the indirect methods. Results of field emergence (E%) and emergence index (EI) are presented in Table 1. The experiments carried out in May and October 1988 did not detect real differences in seed vigour between genotypes. This was due to the optimal soil temperatures during the first 10 days after planting, which, measured at 10 cm depth, ranged from 14.5 to 18°C and 14.5-17°C in May and October, respectively. In Table 2 we present the analysis of variance for April 1989.

Table 1.- Field emergence (E%) and emergence index (EI).

	May 88		October 88		April 89					
					14th		21th		28th	
Genotype	E%	EI	E%	EI	E%	EI	E%	EI	E%	EI
EZ19o2	57.8a+	12.8b	70.4bcd	19.9a	10.2 (6)	40.0	42.6	41.0	50.9	33.8
B14dec	51.3a	12.7b	57.1a	14.7bc	25.0 (1)	35.3	25.0	40.0	41.7	31.4
EZ18o2	61.9a	12.8b	60.9abc	20.3a	6.5 (8)	42.4	45.4	39.8	54.6	30.7
EZ7o2	61.2a	12.2ab	58.8ab	18.4ab	20.4 (4)	36.3	20.4	26.9	30.6	34.4
CM105	63.5a	11.6a	62.9abcd	12.6c	23.1 (3)	30.1	32.4	27.0	39.8	29.7
W64A	63.9a	11.5a	55.6a	16.4abc	13.0 (5)	40.0	25.5	32.0	43.5	32.0
check 1	70.3a	11.7a	74.1d	15.4bc	23.4 (2)	32.3	40.7	29.7	60.0	33.4
check 2	61.9a	11.9ab	71.8cd	15.3bc	7.4 (7)	40.1	25.9	37.7	65.7	31.3

+ 1988 means followed by the same letter do not differ significantly at the 0.05 level according to Duncan's multiple range test

Table 2.- Mean squares (MS) for emergence in the field in 1989.

Source of variation	df	E% MS	EI MS
Genotypes	7	36.7	30.6
Planting dates	2	878.6**	54.3*
Error	14	40.9	14.3
CV		18.9	11.0

*, ** Significant at the 0.05 and 0.01 levels of probability

As may be seen, the planting dates are the main reason for the variation, with no significant differences between genotypes. This was mainly caused by the optimal temperatures of

the third planting, which ranged from 13 to 17°C, much the same situation as in 1988. The first two dates, with 9-13°C and 10-13°C were better predictors of seed vigour. As a result we decided to use only the two first planting dates in 1989 as checks of vigour for the indirect methods, having previously confirmed that their EI were homogeneous.

Vigour tests

a) Germination "per se"

The results of the analysis of variance, and means of the different genotypes are presented in Table 3.

Table 3.- Mean squares (MS) and means for standard germination.

Source of variation	df	MS	Genotype	Mean
Genotypes	7	297.8**	EZ18o2	44.7a+
			B14dec	48.2ab
			EZ19o2	51.4ab
Blocks	1	5.8	EZ7o2	52.2b
			check 1	69.3c
Error	7	8.3	check 2	70.1c
			CM105	70.6c
CV		4.8	W64A	75.2c

** Significant at the 0.01 level of probability
+ Means followed by the same letter do not differ significantly at the 0.05 level according to Duncan's multiple range test.

There are differences among genotypes, with a similar ranking as the field emergence under optimal conditions (germplasm bank data and May 88 trial).

b) PEG

There was no difference of using well water instead of distilled water as a dissolvent. The results of the PEG/DW analysis of variance are presented in Table 4, and means of the different genotypes in Table 5. Analyses of variance show significant differences among genotypes and osmotic potentials in germinated seeds (GS) and first leaf seedlings (FLS) percentages. There is little first leaf development excepted for the control. In general, an increase in negative O.P. implies a decrease in GS and FLS. PEG solutions differenciate genotypes better than the control. There is a significant interaction genotype x O.P. in FLS. In spite of the significant differences, the very high CVs does not recommend the use of the FLS test.

c) Salinity

The results of the analysis of variance, including the control, and means of the different genotypes are presented in Table 6. There is less reduction in GS and FLS than in the case of PEG, showing that, at these concentrations, salt is not toxic. There are differences among genotypes in both GS and FLS, but in this

second parameter we found, as in the PEG method, very high CVs.

Table 4.- Mean squares (MS) for the PEG/Distilled Water test. Germinated seeds (GS) and first leaf seedlings (FLS).

Source of variation	df	GS MS	FLS MS
Osmotic potential	4	1334.2**	5578.3*
Blocks	2	212.6*	1336.4
O.P. error	8	40.0	961.3
Genotypes	7	811.0**	694.0**
O.P. x Gen.	28	106.7	171.1**
Gen. error	70	81.0	68.1
CV of O.P.		8.7	100.0
CV of Gen.		12.4	48.8

*, ** Significant at the 0.05 and 0.01 probability levels

Table 5.- Means of the PEG/DW test. Germinated seeds (GS) and first leaf seedlings (FLS).

Genotype	GS					FLS				
	0*	-1	-2	-4	-6	0	-1	-2	-4	-6
EZ19o2	65.8a+	70.5ab	65.5a	51.2a	48.5ab	44.2a	9.3ab	0.0a	0.0a	0.0a
B14dec	66.8a	72.6ab	74.4ab	76.9bc	56.6abc	38.5a	22.9bcd	13.1ab	14.6a	0.0a
EZ18o2	71.7a	73.5ab	76.7ab	60.2ab	43.8a	50.6a	14.8abc	7.7a	11.5a	0.0a
EZ7o2	78.3a	65.9a	71.5ab	75.2bc	68.5cd	49.2a	43.0e	25.9b	15.5a	3.8a
CM105	82.3a	76.7abc	82.3ab	86.2c	61.7bcd	40.1a	17.4abcd	7.7a	18.2a	0.0a
W64A	86.2a	86.2bc	86.2b	71.5bc	57.3abcd	16.2a	3.8a	0.0a	3.8a	0.0a
check 1	80.7a	76.9abc	83.2ab	75.6bc	71.5d	53.2a	27.4cde	13.3ab	3.8a	3.8a
check 2	84.5a	90.0c	83.3ab	81.1c	71.5d	34.7a	32.9de	27.4b	7.7a	0.0a

* 0, -1, -2, -4, -6: osmotic potentials.
+ Means followed by the same letter do not differ significantly at the 0.05 level according to Duncan's multiple range test

Table 6.- Mean squares (MS) and means for the salinity test. Germinated seeds (GS) and first leaf seedlings (FLS).

Source of variation	df	GS MS	FLS MS
Osmotic potential	2	184.9	4145.3
Blocks	2	17.5	856.9
O.P. error	4	43.3	4104.3
Genotypes	7	490.4**	1059.8**
O.P. x Gen.	14	77.0	136.9
Gen. error	42	44.2	131.5
CV of O.P.		8.8	100.0
CV of Gen.		8.9	38.4

Genotype	GS		FLS	
	-2+	-6	-2	-6
EZ19o2	65.8a#	52.3a	29.2a	0.0a
B14dec	73.6ab	71.0b	25.4a	5.5a
EZ18o2	68.6a	70.4b	41.5a	12.7a
EZ7o2	72.8ab	70.4b	49.4a	32.3a
CM105	86.2c	86.2d	41.5a	20.3a
W64A	72.6ab	65.4b	11.5a	0.0a
check 1	82.3bc	82.3cd	33.5a	31.6a
check 2	75.2ab	73.9bc	36.8a	20.2a

** Significant at the 0.01 probability level
+ -2, -6: osmotic potentials
# Means followed by the same letter do not differ significantly at the 0.05 level according to Duncan's multiple range test

d) Low temperature

The results of the analysis of variance, including the control, and means of the different genotypes are presented in Table 7.

Table 7.- Mean squares (MS) and means for the low temperature test.

Source of variation	df	MS	Genotype	Mean
			EZ18o2	15.5a+
Temperature	1	13137.4**	EZ19o2	25.4ab
Blocks	2	59.5	EZ7o2	31.8bc
Temp. error	2	14.6	B14dec	36.7c
Genotypes	7	1158.9**	check 2	41.5cd
Temp. x Gen.	7	526.2**	W64A	48.4d
Gen. error	28	58.0	check 1	71.5e
			CM105	80.7e
CV of Temp.		6.3		
CV of Gen.		12.6		

** Significant at the 0.01 probability level
+ Means followed by the same letter do not differ significantly at the 0.05 level according to Duncan's multiple range test

There are significant differences among genotypes and temperatures. There is also an interaction temperature x genotypes. Duncan's multiple range tests show that the control differenciate genotypes worse than the LT treatment.

e) Gravel emergence

The results of the analysis of variance, and means of the different genotypes are presented in Table 8.

Table 8.- Mean squares (MS) and means for the percentage of gravel emergence.

Source of variation	df	10d MS	14d MS	Genotype	c10d+	c14d	10d	14d
				EZ19o2	67.4ab#	71.9ab	4.3a	48.0a
Genotypes	7	1158.8**	362.3**	B14dec	63.9a	66.3a	59.1c	63.5b
Gravel	1	3858.8**	1134.2**	EZ18o2	69.5ab	73.8ab	58.7c	71.1b
Blocks	2	101.1	91.8	EZ7o2	76.8abc	81.4bcd	43.1b	65.9b
Gen. x Gravel	7	650.8**	107.2	CM105	77.1abc	85.7cd	71.9cd	79.5b
Error	30	53.0	52.7	W64A	85.7c	90.0d	70.1cd	71.6b
				check 1	79.5bc	79.5bcd	78.1d	78.1b
CV		11.2	9.9	check 2	73.4abc	77.1abc	64.7cd	70.1b

+ c10d, c14d: controls of 10d and 14d, respectively
** Significant at the 0.01 probability level
# Means followed by the same letter do not differ significantly at the 0.05 level according to Duncan's multiple range test

There are significant differences for treatments and genotypes. There is a significant interaction gravel x genotypes when emergence was evaluated ten days after seeding.

f) Seedling growth

Analyses of variance showed no significant differences and very high coefficients of variation for seedling growth (from 30 to 80%) to be considered as a valid test.

g) Conductivity

The results of the analysis of variance, and means of the genotypes are presented in Table 9, showing significant differences among genotypes.

Table 9.- Mean squares (MS) and means for the conductivity.

Source of variation	df	MS	Genotype	Mean
			EZ19o2	13.5e+
Genotypes	7	39.8**	EZ7o2	10.3d
			B14dec	7.4c
Blocks	2	1.1	EZ18o2	5.7b
			W64A	5.5b
Error	14	0.6	check 2	4.6b
			CM105	3.2a
CV		11.7	check 1	3.0a

** Significant at the 0.01 level of probability

\+ Means followed by the same letter do not differ significantly at the 0.05 level according to Duncan's multiple range test.

Selection of methods

The results of the correlations of GERM, PEG/DW-GS, SALT-GS, LT, GE, and C with the first April 89 trial index, and the joint two first trials index, are presented in Table 10.

The tests which were not based in the same treatment and correlated the best with I1 were SALT-GS-2, LT%, and SALT-GS-6, and they were also the best predictors of IT. Correlations among GERM, PEG-DW, SALT, LT, GE, and C are presented in Table 11.

Correlation coefficients between the standard germination and the controls of germination and emergence are high as expected. Since many of the tests are not independent, geometric means of tests that were not based on the same treatment, taken three by three, were calculated (Steiner et al. 1989), and correlations between means and indices analysed. We considered the possible combinations among the best single predictors which had a significant correlation with both indices, and we chose the ones which correlated the best, in their turn, to proceed selecting. These correlations are presented in Table 12.

The three more appropriate tests were SALT-GS-2, LT%, and SALT-GS-6, which are also the best single predictors of I1 and IT. McHughen (1987) found in flax (Linum ussitatissimum L.) that increased vigour rised salt tolerance. All three methods have in common that they are stress tests carried out in plastic trays, the seed is placed on a filter paper over a polyurethane foam soaked in the solution, and they evaluate germination percentage.

Table 10.- Simple correlation coefficients between vigour tests and percentages of the control (%) when useful, with the first April 89 trial index (I1) and the joint two first trials index (IT).

Method	Tr.*	I1	IT
GERM		-0.25	-0.49
PEG/DW-GS	0	-0.21	-0.55
	-1	0.24	0.16
	-1%	0.58	0.79
	-2	-0.37	-0.50
	-4	-0.63	-0.67
	-6	-0.49	-0.60
SALT-GS	-2	-0.85	-0.84
	-2%	-0.77	-0.37
	-6	-0.72	-0.70
	-6%	-0.69	-0.45
LT	10#	-0.79	-0.82
	10%	-0.82	-0.82
GE	c10d	-0.10	-0.56
	c14d	-0.13	-0.59
	10d	-0.35	-0.44
	14d	-0.44	-0.59
C		0.30	0.38

* Correlation coefficients ≥0.620 and 0.790 are significant at P=0.05 and 0.01
\+ Treatment level
\# °C

RESUMEN

Con 40 a 50 métodos diferentes disponibles para el testado del vigor de nascencia, son necesarios procedimientos para elegir el mejor método único o combinación de métodos. El objetivo de este estudio era seleccionar los mejores estimadores de emergencia de maíz (Zea mays L.) en condiciones difíciles. Fueron efectuadas trece pruebas de vigor y varios ensayos de campo sobre seis líneas puras y dos híbridos comerciales. Fueron identificados los mejores estimadores únicos calculando simples coeficientes de correlación. El cálculo de la media geométrica de algunos tests de vigor es un procedimiento para utilizar métodos múltiples que estén correlacionados. Teniendo en cuenta todo esto, los métodos que predicen mejor la nascencia en campo fueron el porcentaje de germinación en solución salina a un potencial osmótico (P.O.) de - 2 bares, porcentaje de germinación a 10°C respecto al control y porcentaje de germinación en solución salina a un P.O. de -6 bares.

Table 11.- Correlation coefficients among vigour tests and controls.

Method		PEG/DW-GS					SALT-GS		LT	GE				C
	Tr.	0	-1	-2	-4	-6	-2	-6	10	c10d	c14d	10d	14d	
GERM		0.86*	0.73	0.83	0.56	0.59	0.63	0.44	0.77	0.79	0.76	0.57	0.57	-0.61
PEG/DW-GS	0		0.62	0.87	0.71	0.64	0.65	0.62	0.65	0.86	0.84	0.77	0.81	-0.70
	-1			0.65	0.37	0.40	0.21	0.17	0.29	0.38	0.30	0.49	0.34	-0.54
	-2				0.73	0.51	0.78	0.75	0.79	0.66	0.61	0.92	0.88	-0.90
	-4					0.74	0.83	0.83	0.70	0.36	0.38	0.75	0.72	-0.66
	-6						0.62	0.56	0.58	0.46	0.35	0.46	0.45	-0.09
SALT-GS	-2							0.92	0.94	0.43	0.45	0.71	0.80	-0.70
	-6								0.75	0.32	0.32	0.83	0.90	-0.82
LT	10									0.56	0.55	0.62	0.68	-0.61
GE	c10d										0.95	0.51	0.59	-0.40
	c14d											0.43	0.57	-0.45
	10d												0.94	-0.95
	14d													-0.94

* Correlation coefficients ≥0.620 and 0.790 are significant at P=0.05 and 0.01

Table 12.- Correlation coefficients between the best single vigour tests and combinations, the index of the first April 89 trial (I1), and the joint two first trials index (IT).

Nº	Method	Tr.	I1	IT
1	SALT-GS	-2	-0.85+	-0.84
2	LT	10%	-0.82	-0.82
3		10	-0.79	-0.82
4	SALT-GS	-2%	-0.77	-0.37
5		-6	-0.72	-0.70
6		-6%	-0.69	-0.45
7	PEG/DW-GS	-4	-0.63	-0.67
Combination				
2-5-7			-0.85	-0.83
1-2-5			-0.84	-0.83
1-2-7			-0.84	-0.83
1-3-5			-0.81	-0.83
3-5-7			-0.80	-0.83
1-3-7			-0.79	-0.82
1-5-7			-0.79	-0.74

+ Correlation coefficients ≥0.620 and 0.790 are significant at P=0.05 and 0.01

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