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Orignal Article

Estimation of general and combining ability effects by Line X Tester Analysis

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Abstract

Using a broad-based genotype as a tester the general combining ability of lines is tested in the top cross method. Line X Tester analysis is an extension of this method in which several testers are used. This design thus provides information about general and specific combining ability of parents and at some time it is helpful in estimating various types of gene effects. This paper constructs and computes Line X Tester methodologies with and without parents. It also constructs and determine the analysis of variance for parents and crosses. The computation of the analysis of variance for RBD design have been done. It also determines the genetic components, standard errors for combining ability effects and proportional contribution of lines, testers with interactions to various genetic components. Rigorous experimentation with multiple data sets have been done and it gives promising results. Economic benefits have been observed to such a large extent by implementation of the methods and analysis discussed.

Keywords: Line, Tester, GCA, Treatments, Parents, Crosses, Combining Ability, Effects, Interactions.

Introduction

In the top cross method, genotype as a tester. the general combining ability of lines is tested. Line X Tester analysis is an extension of this method in which several testers are used. The latter design thus provides information about general and specific combining ability of parents and at some time it is helpful in estimating various types of gene effects. The crossing plan of this design is as follows.

Let us consider '*l*' lines and '*t*' testers. All of these '*l*' lines are crossed to each of '*t*' testers and thus l x t full sib progenies are produced. These progenies along with or without parents i.e., testers and lines, are then tested in a replicated trial using suitable design, say randomized block design[4].

Methodology

Line X Tester Analysis include the following sections

ANOVA for Line X Tester Analysis

The analysis of variance with number of testers (T), number of lines (L) and number of replication (R) are partitioned as shown in Table 1.

Table 1 Analysis of Variance for Line X Tester

Source	df	SS	MS	F
Lines	L-1	LSS	MSSL	MSSL / MSSLT
Testers	T-1	TsSS	MSSTs	TsMS / MSSLT
Line X tester	(L-1)(T-1)	LTSS	MSSLT	LTMS / MSSE
Error	(R-1)(N-1)	ESS	MSSE	

Computation of ANOVA for Line X Tester Analysis Including Parents

This computation of the ANOVA for Line X Tester analysis including parents with number of testers (T), number of lines (L) and number of replications(R) are shown in Table 2.

Table 2 ANOVA for Line X Tester including parents

Source	Df	SS	MS	F	Prob>F
Replications	R-1	RSS	MSSR	MSSR/ MSSE	Prob (R,E)
Treatments	N-1	TrSS	MSSTr	MSSTr/ MSSE	Prob (Tr,E)
Parents	(T+L)-1	PSS	MSSP	MSSP/ MSSE	Prob (P,E)
Parents vs Crosses	PC	PCSS	MSSPC	MSSPC/ MSSE	Prob (PC,E)
Crosses	(T*L)-1	CSS	MSSC	MSSC/ MSSE	Prob (C,E)
Lines	L-1	LSS	MSSL	MSSL/ MSSE	Prob (L,LT)
Testers	T-1	TsSS	MSSTs	MSSTs/ MSSE	Prob (Ts,LT)
Line X Tester	(L-1) (T-1)	LTSS	MSSLT	MSSLT/ MSSE	Prob (LT,E)
Error	(R-1) (N-1)	ESS	MSSE		
Total	(NR-1)	TSS			

Computation of ANOVA for Line X Tester Analysis Including Parents by Using Following Formulae

Correction Factor $(C.F.)_{Total} = (Grand\_Total)^2 / N^* r$

where

$N = (LxT) + (L+T)$

Correction Factor Parent $(C.F.)_{Parent}$ = (Grand Total for Parents)^2/ R(T + L)

Correction Factor Crosses $(\mathbf{C.F.})_{Crosses}$ = (Grand_ Total for Crosses)^2/ R (T * L)

Replication Sum of Square (**RSS**) = 1 / N $(\Sigma y_{.j}^2)$ - $(C.F.)_{Total}$

where

$\Sigma Y_{.j}^2 = 1 / N (Y_{.1}^2 + Y_{.2}^2 + Y_{.3}^2 + \ldots\ldots Y_{.n}^2)$

Treatment Sum of Square **(TrSS)** = 1 / R $(\Sigma y_{i.}^2)$ – $\mathbf{(C.F.)}_{Total}$

where

$\Sigma Y_i^2 = 1 / R (Y_{1.}^2 + Y2.^2 + Y3.^2 + \ldots\ldots Yn.^2)$

Total Sum of Square **(TSS)** = $\Sigma \Sigma y_{i\ j}^2$ - $\mathbf{(C.F.)}_{Total}$

Error Sum of Square **(ESS)** = TSS - TrSS - RSS

Parents Sum of Square **(PSS)** = 1 / R $(\Sigma y_{.j}^2)$ parent - $\mathbf{(C.F.)}_{parent}$

where

$\Sigma Y_{.j}^2 = 1 / R (Y_{.1}^2 + Y_{.2}^2 + Y_{.3}^2 + \ldots\ldots Y_{.n}^2)_{parent}$

Parents .vs. Crosses Sum of Square **(PCSS)** = $(C.F.)_{Crosses} + (C.F.)_{Parent} - (C.F.)_{Total}$

Crosses Sum of Square (CSS) = 1 / R $(\Sigma y_{i.}^2)$ crosses – $(C.F.)_{crosses}$

where

$\Sigma Y_{i.}^2 = 1/R (Y_{1.}^2 + Y_{2.}^2 + Y_{3.}^2 + \ldots\ldots Y_{n.}^2)_{crosses}$

Lines Sum of Square (LSS) = 1 / (R * T) $(\Sigma y_{i.}^2)_{crosses}$ – $(C.F.)_{crosses}$

where

$\Sigma Y_{i.}^2 = 1 / R (Y_{1.}^2 + Y_{2.}^2 + Y_{3.}^2 + \ldots\ldots Y_{n.}^2)_{crosses}$

Tester Sum of Square (**TsSS**) =1 / (R * T)$(\Sigma Y_{.j}^2)$ Crosses - $\mathbf{(C.F.)}_{Crosses}$

where

$\Sigma Y_{.j}^2 = 1 / R (Y_{.1}^2 + Y_{.2}^2 + Y_{.3}^2 + \ldots\ldots Y_{.n}^2)_{Crosses}$

Lines X Tester Sum of Square (**LTSS**) = CSS – LSS - TsSS

Mean Sum of Square due to Replication (**MSSR**) = RSS / R - 1

Mean Sum of Square due to Treatment (**MSSTr**) = TrSS / N - 1

Mean Sum of Square due to Parents (**MSSP**) = PSS / ((T + L) – 1)

Mean Sum of Square due to Parents and Crosses (**MSSPC**) = PCSS / [N – 1] - [(T + L) - 1] - [(T * L) – 1]

Mean Sum of Square due to Crosses (**MSSC**) = CSS / ((T X L) – 1)

Mean Sum of Square due to Lines (**MSSL**) = LSS / L - 1

Mean Sum of Square due to testers (**MSTs**) = TsSS / T - 1

Mean Sum of Square due to Line X Tester (**MSSLT**) = LTSS / (T – 1) (L – 1)

Mean Sum of Square due to Error (**MSSE**) = ESS / (R – 1) (N – 1)

ANOVA for Line X Tester Including Parents

where

PC = [N – 1] - [(T + L) - 1] - [(T * L)– 1]

Prob (R,E) = Probability due to replications and error for degree of freedom (R - 1)

Prob (Tr,E) = Probability due to treatment and error for degree of freedom (N - 1)

Prob (P,E) = Probability due to parents and error for degree of freedom (T + L) - 1

Table 3 Analysis of Variance for Line X Tester

Source	df	SS	MS	F	Prob>F
Replications	R-1	RSS	MSSR	MSSR/ MSSE	Prob (R,E)
Treatments	N-1	TrSS	MSSTr	MSSTr/ MSSE	Prob (Tr,E)
Parents	(T+L)-1	PSS	MSSP	MSSP/ MSSE	Prob (P,E)
Parents vs Crosses	PC	PCSS	MSSPC	MSSPC/ MSSE	Prob (PC,E)
Crosses	(T*L)-1	CSS	MSSC	MSSC/ MSSE	Prob (C,E)
Lines	L-1	LSS	MSSL	MSSL/ MSSE	Prob (L,LT)
Testers	T-1	TsSS	MSSTs	MSSTs/ MSSE	Prob (Ts,LT)
Line X Tester	(L-1) (T-1)	LTSS	MSSLT	MSSLT/ MSSE	Prob (LT,E)
Error	(R-1) (N-1)	ESS	MSSE		
Total	(NR-1)	TSS			

Prob (PC,E) = Probability due to parents, crosses and error for degree of freedom PC

Prob (C,E) = Probability due to crosses and error for degree of freedom (T * l) - 1

Prob (L,LT) = Probability due to lines and Line X Tester for degree of freedom (L - 1)

Prob (Ts,LT) = Probability due to testers and Line X Tester for degree of freedom (T - 1)

Prob (LT,E) = Probability due to Line X Tester and error for degree of freedom (L-1) (T-1)

Computation of ANOVA for Parents and Crosses

The computation of Anova with parents and crosses with number of testers(T), number of lines(L) and number of replications(R) are shown in Table 4.

Correction Factor (C.F.) Total = $(Grand\_Total)^2 / N * R$

where

$N = (L \times T) + (L + T)$

Correction Factor Parent $(C.F.)_{Parent}$ = $(Grand\_Total\ for\ Parents)^2 / R\ (T + L)$

Correction Factor Crosses $(C.F.)_{Crosses}$ = $(Grand\_Total\ for\ Crosses)^2 / R\ (T * L)$

Treatment Sum of Square (TrSS) = $1 / R\ (\Sigma\ y_i.^2) - (C.F.)_{Total}$

where

$\Sigma\ Y_i.^2 = 1 / R\ (Y_1.^2 + Y_2.^2 + Y_3.^2 + \ldots\ldots Y_n.^2)$

Replication Sum of Square **(RSS)** = $1 / N\ (\Sigma\ y_{.j}^2) - (C.F.)_{Total}$

where

$\Sigma\ Y_{.j}^2 = 1 / N\ (Y_{.1}^2 + Y_{.2}^2 + Y_{.3}^2 + \ldots\ldots Y_{.n}^2)$

Total Sum of Square **(TSS)** = $\Sigma\Sigma\ Y_{i\ j}^2 - (C.F.)_{Total}$

Error Sum of Square **(ESS)** = TSS - TrSS - RSS

Crosses Sum of Square **(CrSS)** = $1 / R\ (\Sigma\ Y_i.^2_{Crosses} - \mathbf{(C.F.)}_{Crosses}$

where

$\Sigma\ Y_i.^2 = 1 / R\ (Y_1.^2 + Y_2.^2 + Y_3.^2 + \ldots\ldots Y_n.^2)_{Crosses}$

Parents Sum of Square **(PSS)** = $1 / R\ (\Sigma\ Y_{.j}^2)_{Parent} - (C.F.)_{Parent}$

where

$\Sigma\ Y_{.j}^2 = 1 / R\ (Y_{.1}^2 + Y_{.2}^2 + Y_{.3}^2 + \ldots\ldots Y_{.n}^2)_{arent}$ Error Sum of Square **(ESS)** = $\mathbf{(C.F.)}_{Crosses} + (C.F.)_{Parent} - \mathbf{(C.F.)}_{Total}$

Mean Sum of Square due to Replications **(MSSR)** = RSS / R - 1

Mean Sum of Square due to Treatment **(MSSTr)** = TrSS / N - 1

Mean Sum of Square due to Parents **(MSSP)** = PSS / ((T + L) – 1)

Mean Sum of Square due to Crosses **(MSSC)** = CSS / ((T X L) – 1)

Mean Sum of Square due to Parents and Crosses **(MSSPC)** = PCSS / [N-1] - [(T + L) - 1] - [(T * L) –1]

Mean Sum of Square due to Error **(MSSE)** = ESS / (R – 1) (N – 1)

Anova with Parents and Crosses

Table 4 Analysis of Variance for Line X Tester for Parents and Crosses

Source	df	SS	MS	F	Prob>F
Replications	R-1	RSS	MSSR	MSSR / MSSE	Prob (R,E)
Treatments	N-1	TrSS	MSSTr	MSSTr / MSSE	Prob (Tr,E)
Parents	(T+L)-1	PSS	MSSP	MSSP/ MSSE	Prob (P,E)
Crosses	(T*L)-1	CSS	MSSC	MSSC/ MSSE	Prob (C,E)
Parents vs Crosses	PC	PCSS	MSSPC	MSSPC/ MSSE	Prob (PC,E)
Error	(N-1) x (R-1)	ESS	MSSE		

where

PC = [N – 1] - [(T + L) – 1] - [(T * L) – 1]

Prob (R,E) = Probability due to replications and

error for degree of freedom (R - 1)

Prob (Tr,E) = Probability due to treatments and

error for degree of freedom (N - 1)

Prob (P,E) = Probability due to parents and error for degree of freedom (T + 1) - 1

Prob (C, E) = Probability due to crosses and error for degree of freedom (T * L) - 1

Prob (PC,E) = Probability due to parents and crosses for degree of freedom PC

Computation of Analysis of Variance for Simple R.B.D.

It is computation of analysis of variance for simple RBD in Line X Tester analysis shown in Table 5 with number of testers(T), number of lines(L) and number of replications(R).

Correction Factor **(C.F.)** = $(Grand\_Total)^2 / N * R$

where

N = (L X T) + (L + T)

Treatment Sum of Square **(TrSS)** = $1 / R (\Sigma Y_i^2)$ - C.F.

where

$\Sigma Y_i.^2 = 1 / R (Y_1.^2 + Y_2.^2 + Y_3.^2 + ... Y_n.^2)$

Replication Sum of Square **(RSS)** = $1 / N (\Sigma Y._j^2)$ - C.F.

where

$\Sigma Y._j^2 = 1 / N (Y._1^2 + Y._2^2 + Y._3^2 + ... Y._n^2)$parent

Total Sum of Square **(TSS)** = $\Sigma \Sigma Y_{i\ j}^2$ - C.F.

Error Sum of Square **(ESS)** = TSS - TrSS - RSS

Mean Sum of Square due to Replications **(MSSR)** = RSS / R - 1

Mean Sum of Square due to Treatment **(MSSTr)** = TrSS / N - 1

Mean Sum of Square due to error **(MSSE)** = ESS / (R - 1) (N – 1)

Table 5 Analysis of Variance for Line X Tester RBD

Source	df	SS	MS	F	Prob>F
Replications	R-1	RSS	MSSR	MSSR/ MSSE	Prob (R,E)
Treatments	N-1	TrSS	MSSTr	MSSTr/ MSSE	Prob (Tr,E)
Error	(R-1)/ (N-1)	ESS	MSSE		
Total	NR-1	TSS			

Prob (R,E) = Probability due to replications and error for degree of freedom (R – 1)

Prob (Tr,E) = Probability due to treatments and error for degree of freedom (N - 1)

Computation of Estimation of GCA Effects

(a) Lines

$g_i = x_i$ ../ tr - x../ ltr

where,

l = number of lines

t = number of testers

r = number of replications

Check $\Sigma g_i = 0$

(b) Testers

$g_i = x_{.j.}$ / lr - x... / ltr

where,

l = number of lines

t = number of testers

r = number of replications

Check $\Sigma g_i = 0$

Computation of Standard Errors for Combining Ability Effects

S.E.(gca for line) = $(M_e / r \times t)^{1/2}$

S.E.(gca for tester) = $(M_e / r \times l)^{1/2}$

S.E.(gca for effects) = $(M_e / r)^{1/2}$

S.E.$(g_i - g_j)$line = $(2M_e / r \times t)^{1/2}$

S.E.$(g_i - g_j)$tester = $(2M_e / l \times r)^{1/2}$

S.E.$(s_{ij} - s_{tl})$ = $(2M_e / r)^{1/2}$

Computation of Genetic Components

Cov H.S.(line) = $(M_l - M_{l \times t}) / rt$

Cov H.S.(tester) = $(M_t - M_{l \times t}) / rl$

Cov H.S.(average) = $1/r$ (2lt - l - t) [(l-1) (M_l) + (t-1) (M_t) / 1+t-2 - $M_{l \times t}$]

Cov F.S. = $(M_l - M_e) + (M_t - M_e) + (M_l x_t - M_e) / 3xr$

σ^2 gca = Cov H.S. = $[1+F/4]^2 \sigma^2 A$

Calculate $\sigma^2 A$ with F=0 and F=1

σ^2 sca = $M_{lxt} - M_e / r$

$\sigma^2 sca = [1+F / 2]^2 \sigma^2 D$

Calculate with F=0 and F=1

Computation of proportional contribution of Lines, Testers and their Interactions to Total Variance

Contribution of Lines = SS(l) x 100 / SS(Crosses)

Contribution of Testers = SS(t) x 100 / SS(Crosses)

$$\text{Contribution of } (l \times t) = SS(l \times t) \times 100 / SS(\text{Crosses})$$

Experimental Analysis

Rigorous experimentation has been done with real data sets leads to very efficient and promising results. Generalized multithreaded [1-3] object-oriented computer programs have been developed. The result of a real data set with 3 lines and 5 tester is mentioned below

Analysis of Variance of Simple RBD

Source	df	SS	MS	F	Prob>F
Replications	3	83.000117	666706	0.303826	0.822519
Treatments	22	32553.202391	1479.691018	16.249429	0.000010
Error	6	6010.032983	91.061106		
Total	91	38646.235491			

ANOVA with Parents and Crosses

Source	df	SS	MS	F	Prob>F
Replications	3	83.000117			
Treatments	22	32553.202391			
Parents	7	6299.885187	899.983598	9.883293	0.000010
Crosses	14	26199.654333	1871.403881	20.551078	0.000010
P.vs.C.	1	53.662870	53.662870	0.589306	0.445425
Error	6	6010.032983	91.061106		

ANOVA for Line X Tester Analysis

Source	df	SS	MS	F	Prob>F
Lines	2	10114.343613	5057.171807	3.538881	0.079252
Testers	4	4653.059400	1163.264850	0.814023	0.550400
LineXTesters	8	11432.251320	1429.031415	15.693104	0.000010
Error	66	6010.032983	91.061106		

ANOVA for Line X Tester Analysis Including Parents

Source	df	SS	MS	F	Prob>F
Replications	3	83.000117	27.666706	0.303826	0.822519
Treatments	22	32553.202391	1479.691018	16.249429	0.000010
Parents	7	6299.885187	899.983598	9.883293	0.000010
P. vs. C.	1	53.662870	53.662870	0.589306	0.000000
Crosses	14	26199.654333	1871.403881	20.551078	0.000010
Lines	2	10114.343613	5057.171807	3.538881	0.079252
Testers	4	4653.059400	1163.264850	0.814023	0.550400
LineXTesters	8	11432.251320	1429.031415	15.693104	0.000010
Error	66	6010.032983	91.061106		

Summation of GCA Effects due to lines

GCA Effects	Value
g1	-6.2897
g2	18.0843
g3	-11.7947
Summation of All g's	-0.0000

Summation of SCA Effects due to testers

SCA Effects	Value
S14	1.9563
S15	28.8030
S16	-23.8470
S17	-11.4237
S18	4.5113
S24	-5.3177
S25	-2.3260
S26	10.6790
S27	8.6723
S28	-11.7077
S34	3.3613
S35	-26.4770
S36	13.1680
S37	2.7513
S38	7.1963
Summation of All Sij's	0.0000

Summation of GCA Effects due to Testers

GCA Effects	Value
g4	-13.3533
g5	-1.1100
g6	-3.4600
g7	4.7417
g8	13.1817
Summation of All g's	0.0000

Standard Errors for Combining Ability Effects

STANDARD ERROR	Value
SE (gca For Line)	2.1338
SE (gca For Tester)	2.7547
SE (sca Effects)	4.7713
SE (gi -gj) Line	3.0176
SE (gi -gj) Tester	3.8957
SE (Sij -Skl)	6.7476

Calculation of Genetic Component

GENETIC COMPONENTS	Value
Cov. H.S. (Line)	181.4070
Cov. H.S. (Tester)	-22.1472
Cov. H.S. (Average)	11.7296
Cov. F.S	606.8707

Proportional Contribution of Lines Testers And Their Interactions To Total Variance

PROPORTIONAL CONTRIBUTION	Value
Contribution Lines	38.6049
Contribution Testers	17.7600
Contribution LinesXTesters	43.6351

Conclusion

Line X Tester analysis is an extension of this method in which several testers are used. This paper constructs and computes Line X Tester methodologies with and without parents. It also constructs and determine the analysis of variance for parents and crosses. The computation of the analysis of variance for RBD design have been done. It also determines the genetic components, standard errors for combining ability effects and proportional contribution of lines, testers with interactions to various genetic components. Rigorous experimentation with multiple data sets have been done and it gives promising results. Implementation of these methods leads to economic benefits.

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