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Association Between *GCA* and *Per Se* Performance of Parents and Hybrids for Grain Yield, its Attributing Traits and Late Wilt Disease (*Harpophora maydis*) Resistance in Maize (*Zea mays* L.)

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A B S T R A C T

Initial evaluation of in breds for general combining ability (*gca*) enables plant breeders to discard undesirable ones and identify those that are potential for the production of superior hybrids. In this context, 11 parental in breds which are contrasting for Late Wilt Disease (LWD) reaction (4 LWD resistant and 7 LWD susceptible) and yielding ability were selected and were evaluated for their *gca* related to grain yield plant^{-1}, its attributing traits and reaction to LWD infection. The analysis of variance revealed significant differences among the inbred lines for their *per se* performance as well as their *gca*. Similarly, the hybrids differed significantly for *per se* performance and their specific combining ability (*sca*) effects for all the traits. The non-significant correlation between *per se* performance and *gca* effects suggested that *per se* performance of inbred lines is not a good indicator of their *gca* effects for any of the traits studied including reaction to LWD infection. However, significant positive and fairly high magnitude of correlation between *per se* performance of hybrids and sum of parental *gca* effects for all the traits under study including reaction to LWD infection indicating that parental *gca* effect is good indicator of *per se* performance of hybrids. hence, parents having higher *gca* effects are expected to give good performing hybrids.

Introduction

Maize (*Zea mays* L.) is an important cereal crop in the world and a primary staple food in many developing countries that provides food, feed, fuel and other industrial raw materials. But now a days it is affected by many biotic and abiotic stresses, among them biotic stresses are predominant, hence, resistance breeding for LWD is at most important. In maize single cross hybrids are the major cultivar types used for commercial production in most parts of the world. Hybrids have played a vital role in increasing the area and productivity of maize.

Superior hybrids are produced if the parents involved have good general combining ability (*gca*), which is the relative ability of a genotype to transmit its genes with additive effects to its progeny. The concept of *gca* (Sprague &Tatum, 1942) is a widely accepted criteria for assessing the inbreds for their use as parents in the development of heterotic hybrids. Testing of inbreds for their *gca* effects enables plant breeders to discard most of the undesirable inbreds (low *per se* performance and LWD susceptible) and allows greater expenditure of resources on most promising ones and identifies those that are desirable for the production of superior hybrids (Bernardo, 2010; Ali *et al.*, 2011; Ai-Zhi& Zheng, 2012; Fasahat *et al.*, 2016; Hosana *et al.*, 2015).

Apart from providing an objective criterion for choosing parents, *gca* also provides useful clues about mode of action of genes controlling economically important traits. Another utility of *gca* of the parents is their predictive power of hybrid *per se* performance in the absence of significant hybrid specific combining ability (*sca*) effects. Under these premises, an investigation was undertaken to assess the relationship between *gca* and *per se* performance of parents and hybrids of maize.

Materials and Methods

Basic material

Based on prior evaluation of 300 inbred lines of maize (Aruna *et al.*, 2018), 11 were selected based on LWD reaction and grain yield plant^{-1} and they constituted the basic genetic material.

Development and field evaluation of experimental material

These 11 inbreds were crossed following full diallel mating design (Hayman, 1954) to develop 110 single cross hybrids (SCH) during *kharif* 2018 at the experimental plots of the Department of Genetics and Plant Breeding (GPB), University of Agricultural Sciences (UAS), Gandhi Krishi Vignana Kendra (GKVK), Bengaluru. The resultant 110 SCH, their parents and five checks *viz*., Hema and Nithyashree for yield evaluation and P3501 and NK 6240 LWD screening constituted the experimental material and were evaluated following simple lattice design in two different sets of experiments with two replications. Each entry was sown in one row of 3m length with a spacing of 0.6 m × 0.3 m. All the recommended package of practices was followed to raise a healthy crop.

Sampling of plants and data recorded

Data were recorded on five randomly selected competent plants in both the replications, on each hybrid, parent and checks for LWD reaction, grain yield plant^{-1} and its attributing traits.

Statistical analysis

Replication wise mean data of hybrids, parents and checks was used for statistical analysis. Data of F_1 hybrids were subjected to combining ability analysis following diallel model (Hayman, 1954; Griffing, 1956). The *gca* effects of 11 lines were estimated and their statistical significance was examined using ‘t’ test.

Relationship of *gca effects* of inbred lines with their *per se* performance

Relationship between *per se* performance of 11 inbred lines and their *gca* effects were determined by estimating Spearman’s Rank Correlation Coefficient for all the traits.

$$r = 1 - \frac{6Ed^2}{n(n^2 - 1)}$$

Where,
r = Spearman’s Rank Correlation Coefficient
d = Differences in ranks given to per se performance of hybrids and sum of

their parental gca effects based on magnitude and direction

n = Number of pairs of values

Higher magnitude of positive significant and non-significant correlation indicates good and poor predictive power of *per se* performance, respectively.

Relationship of hybrid *per se* performance with sum of parental *gca* effects

Pearson's Correlation Coefficients between hybrids *per se* performance and sum of *gca* effects of their parents were estimated for all traits (Schrag *et al.,* 2009) including LWD reaction. Significant correlation with fairly high coefficients of correlation and determination was interpreted as high predictability of hybrid *per se* performance based on their sum of parental *gca* effects.

Results and Discussion

Analysis of variance (ANOVA)

Simple Lattice design ANOVA revealed there is significant difference among the hybrids for all the traits under study including LWD disease reaction indicating diverse nature of the crosses used in the study, Hence the data is further considered for diallel analysis. Diallel ANOVA indicated significant differences among single cross hybrids for all the traits (Table 1). Significant mean squares due to inbreds and hybrids suggested substantial variability for *gca* effects of inbreds and *sca* effects of their crosses for all the traits including LWD reaction. Significant variances among the crosses could be attributed to greater diversity between inbreds for the traits considered. The mean squares attributable to inbreds and crosses for all the traits indicated greater contribution of the inbreds towards total variation among the hybrids (Kanagarasu *et al.*, 2010).

General combining ability of inbred lines

The practical phase of maize hybrid breeding is identification of potential inbred lines with high *gca* for use as parents for developing hybrids that are superior to existing ones (El-Hosary, 2014). Identification of such elite inbred lines is the major strategy adopted by most commercial plant breeders to maximize genetic gain per unit time and resources.

This assumption is based on the reports that *gca* is controlled by additive effect genes which control the inheritance of phenotypes that are fixable (Ai-Zhi& Zheng, 2012). In the present study, the inbred lines differed widely for their *gca* effects for all the quantitative traits including for LWD reaction.

The differences in *gca* effects of the inbreds are attributable to differences in frequencies of genes that are transmitted to the progeny with the additive effects (Falconer & Mackay, 1996). The differences in gene frequencies among the inbreds suggest their significant genotypic differences, thus justifying their selection for the present study.

Different inbred lines were desirable general combiners in both direction and magnitude for different traits (Table 2). Thus, no single line was a desirable combiner for all the seven traits. For instance, inbreds such as 97B and MAI-345 were desirable general combiners for ear circumference, 100 grain weight and grain yield plant^{-1}.

However, inbred line 40458 is best general combiner for kernel rows ear^{-1} and kernels row^{-1}. Inbred lines MAI-21 and MAI-345 were found to be good general combiners for LWD reaction. It should however be noted that the estimates of *gca* effects of 11 inbred lines are relative to and are dependent on particular set of parents included in the experiment (Fasahat *et al.*, 2016).

Table.1 ANOVA of 11 × 11 full diallel crosses and their parents for grain yield its component traits and reaction to LWD infection in maize

Source of variation	Degrees of freedom	Mean sum of squares						
		Ear length (cm)	Ear circumference (cm)	Kernel rows cob $^{-1}$	Kernels row^{-1}	100 grain weight (g)	Grain yield plant^{-1} (g)	Response to LWD reaction
Replication	1	0.86	1.87	0.14	0.06	28.06	986.72	0.15
Inbreds + Hybrids	120	7.15***	1.42***	2.09***	56.22*	34.15***	1584.06***	1.33***
Inbreds	10	14.20***	4.48***	5.69***	132.80***	18.70**	1265.25***	3.43***
Hybrids	109	5.63***	1.15***	1.63**	37.97***	25.24***	928.32***	1.12***
Indreds Vs. Hybrids	1	102.10***	0.01	17.04***	1279.17***	1159.76***	76248.34***	2.88*
Straight crosses	54	6.30***	1.26***	1.70**	41.25***	23.58***	1112.79***	0.99**
Reciprocal crosses	54	5.06***	1.06***	1.58**	35.38***	27.31***	754.21***	1.25***
Straight vs. Reciprocal crosses	1	0.64	0.00	0.01	1.13	3.31	369.33	1.39
Error	120	1.81	0.40	0.93	12.87	6.99	110.70	0.52
Total	241	4.46	0.91	1.50	34.40	20.67	849.91	0.92
GCA	10	10.57***	1.45***	3.52***	60.04***	23.86***	1175.29***	1.85***
SCA	55	3.56***	0.63***	0.81**	31.11***	18.37***	1115.51***	0.58***
Error	120	0.90	0.19	0.46	6.43	3.49	55.35	0.25

*Significant at P = 0.05; ** Significant at P = 0.01; *** Significant at P = 0.001

Table.2 Estimates of general combining ability effects of 11 parents for grain yield, its component traits and reaction to LWD infection in maize

Parental lines	Ear length (cm)	Ear circumference (cm)	Kernel rows ear^{-1}	Kernels row^{-1}	100 grain weight (g)	Grain yield plant^{-1} (g)	Response to LWD reaction
97B	0.18	0.57***	0.19	1.96***	1.23**	15.82***	-0.03
MQ43	-0.67***	-0.22*	0.13	-2.56***	-0.68	-13.30***	0.22*
MAI-21	0.10	0.12	0.44**	-0.98	0.06	4.22**	-0.48***
MAI-740	-1.39***	0.35***	-0.18	-3.80***	0.20	-5.84***	0.65***
70	-0.71***	0.31***	0.19	-1.51**	1.20**	1.63	-0.12
59	-0.86***	-0.18*	-0.97***	-1.63**	1.74***	-5.66***	0.13
40297	1.27***	0.12	-0.74***	0.93	0.36	-0.26	0.27*
40458	1.83***	-0.64***	0.51***	4.44***	-2.44***	4.10**	-0.15
18758	0.55**	-0.40***	0.14	2.51***	-2.80***	-10.18***	-0.004
MAI-334	-0.49*	-0.31***	-0.12	-0.17	-0.44	-3.14*	-0.16
MAI-345	0.19	0.28**	0.39**	0.81	1.56***	12.61***	-0.33**
$G_i - G_j$ @ 5%	0.6390**	0.2996**	0.4575**	1.7043**	1.2563**	4.9982**	0.3417**
$G_i - G_j$ @ 1%	0.9089**	0.4262**	0.6508**	2.4241**	1.7870**	7.1092**	0.486**

***** Significant at P = 0.05; ** Significant at P = 0.01; *** Significant at P = 0.001

Table.3 Association of genetic parameters with grain yield, its attributing traits and reaction to LWD infection in maize

Quantitative traits	Correlation of	
	Parental *gca effects* vs. *per se* performance of parents	Sum of parental *gca effects* vs. *per se* performance of hybrids
Ear length (cm)	0.49	0.79**
Ear circumference (cm)	0.16	0.73**
Kernel row cob^{-1}	0.76**	0.62**
Kernels row^{-1}	0.456	0.75**
100 grain weight (g)	0.55	0.20**
Grain yield plant^{-1} (g)	0.19	0.62**
Response to LWD infection	0.54	0.52**

** Correlation is significant at P = 0.01; * Correlation is significant at the P = 0.05

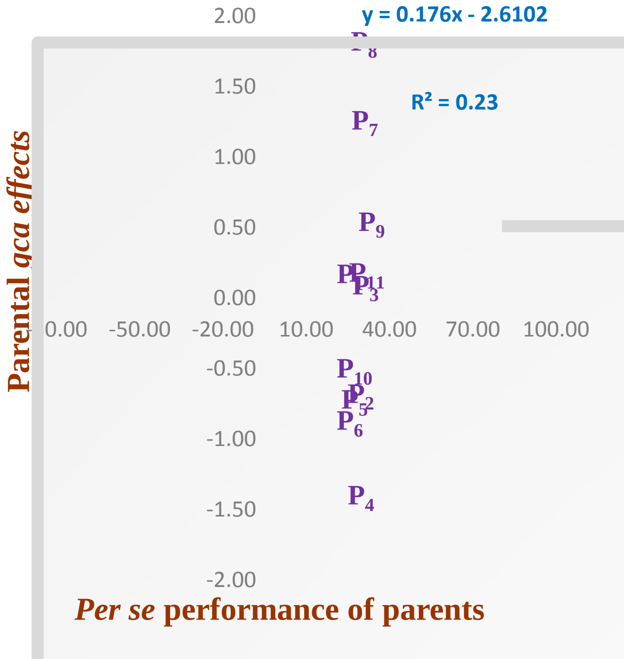

Fig.1 Correlation of *per se* performance of inbreds with their *gca* effects for ear length (cm)

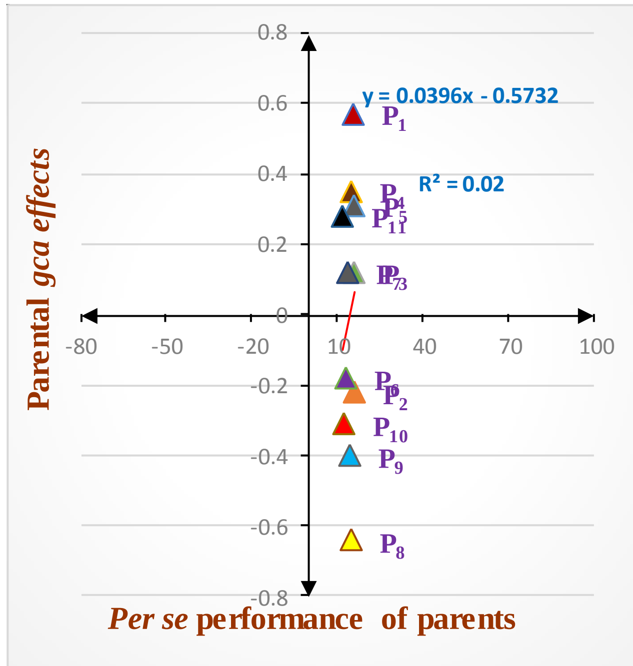

Fig.2 Correlation of *per se* performance of inbreds with their *gca* effects for ear circumference (cm)

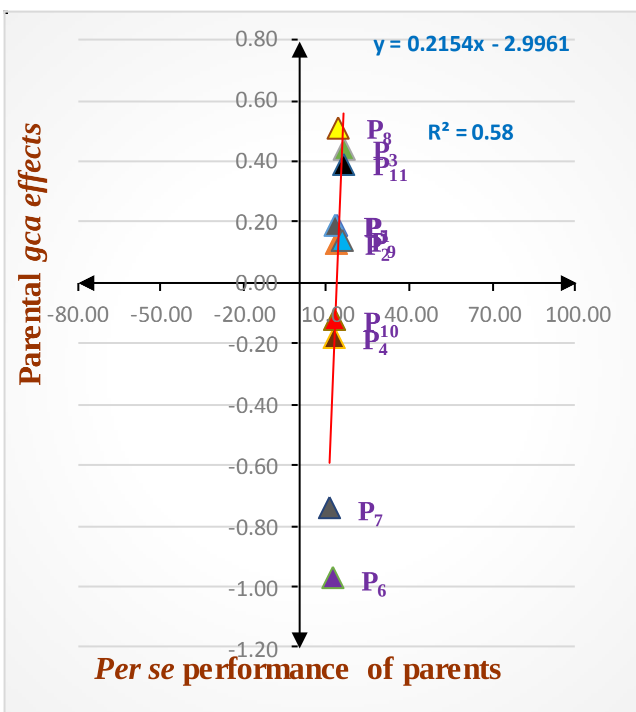

Fig.3 Correlation of *per se* performance of inbreds with their *gca* effects for kernel row cob^{-1}

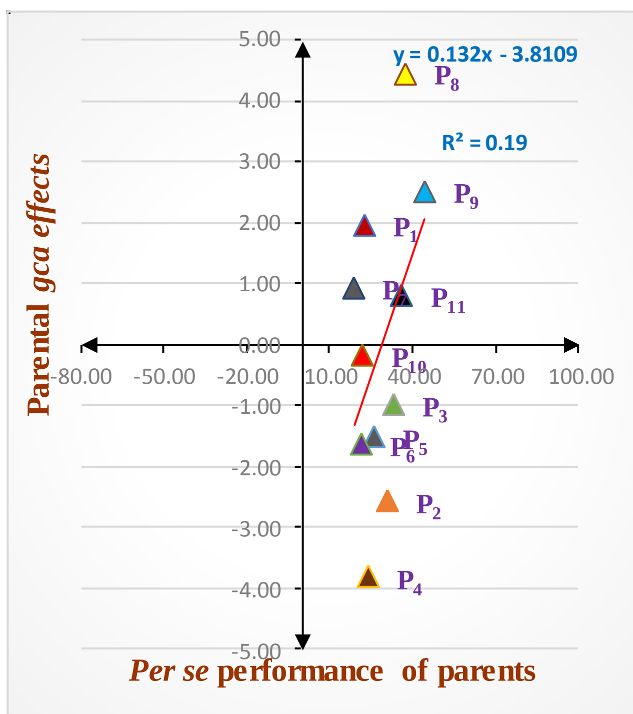

Fig.4 Correlation of *per se* performance of inbreds with their *gca* effects for kernels row^{-1}

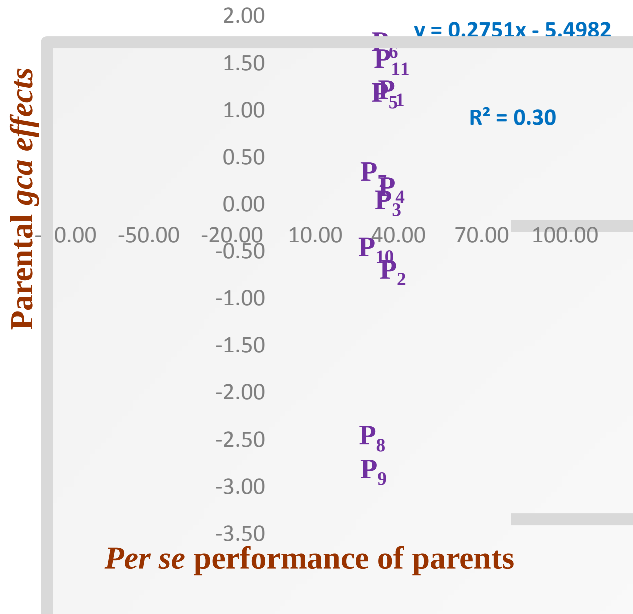

Fig.5 Correlation of *per se* performance of inbreds with their *gca* effects for 100 grain weight (g)

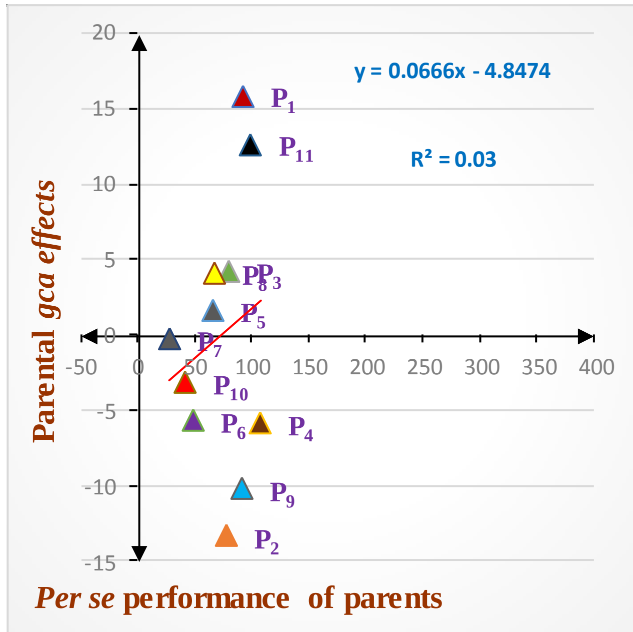

Fig.6 Correlation of *per se* performance of inbreds with their *gca* effects for grain yield plant $^{-1}$ (g)

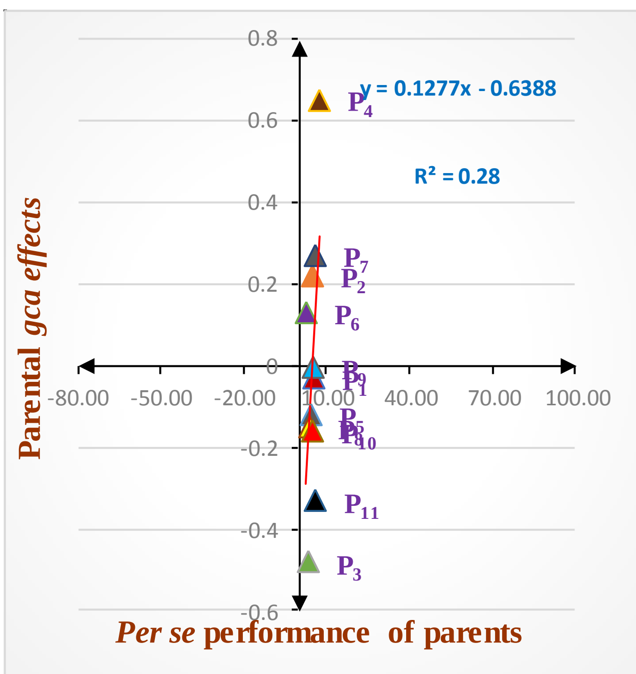

Fig.7 Correlation of *per se* performance of inbreds with their *gca* effects for response to LWD infection

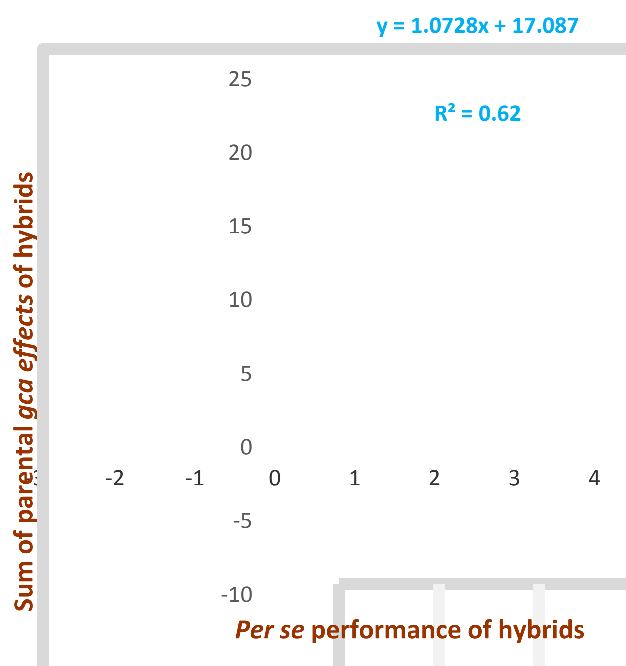

Fig.8 Correlation of hybrid *per se* performance with sum of parental *gca* effects for ear length (cm)

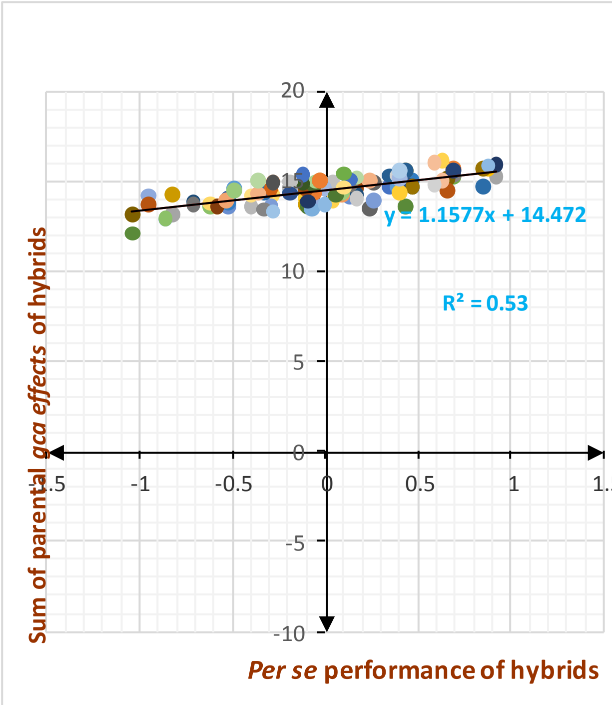

Fig.9 Correlation of hybrid *per se* performance with sum of parental *gca* effects for ear circumference (cm)

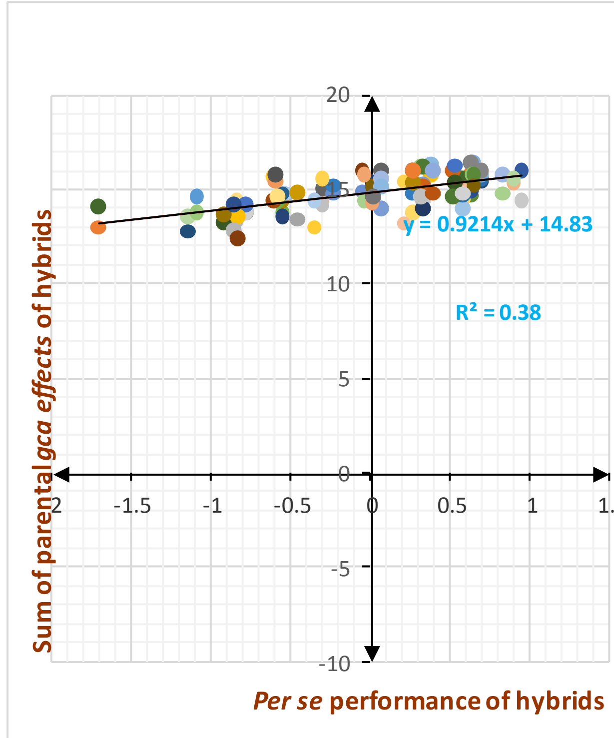

Fig.10 Correlation of hybrid *per se* performance with sum of parental *gca* effects for kernel row cob $^{-1}$

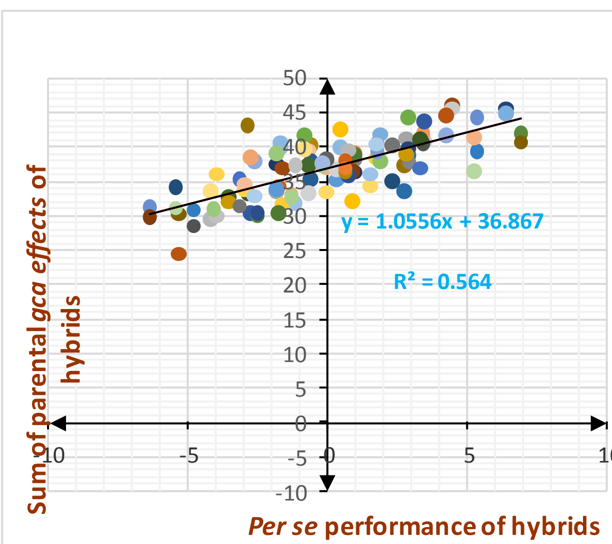

Fig.11 Correlation of hybrid *per se* performance with sum of parental *gca* effects for kernels row $^{-1}$

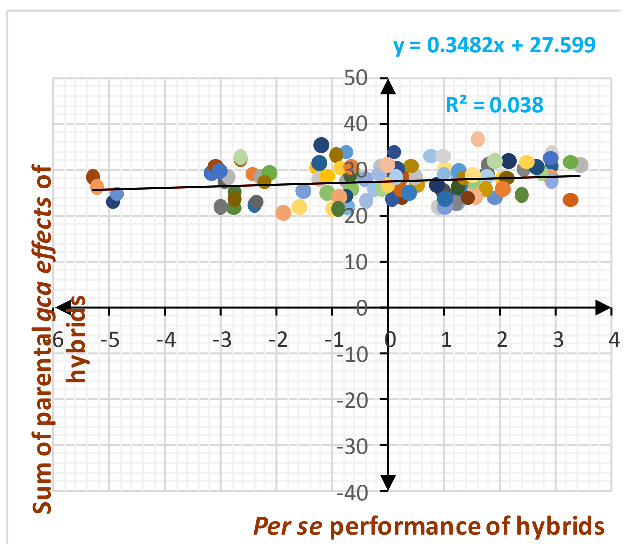

Fig.12 Correlation of hybrid *per se* performance with sum of parental *gca* effects for 100 grain weight (g)

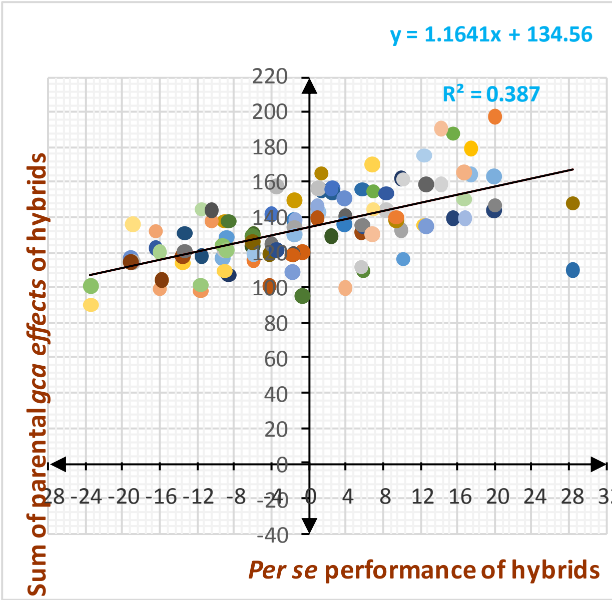

Fig.13 Correlation of hybrid *per se* performance with sum of parental *gca* effects for grain yield plant $^{-1}$(g)

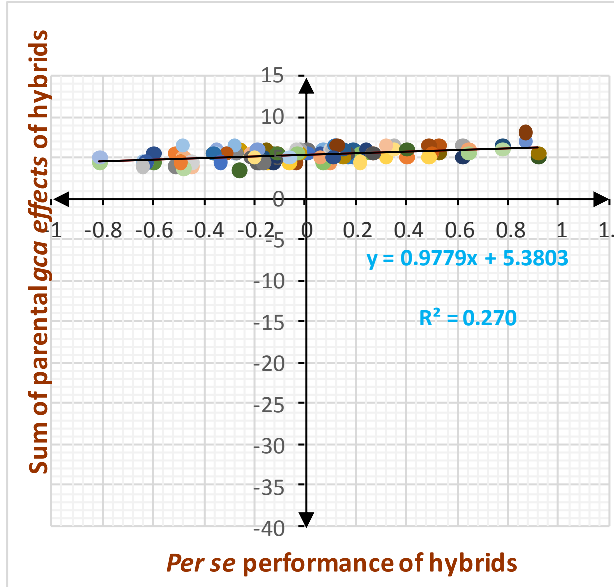

Fig.14 Correlation of hybrid *per se* performance with sum of parental *gca* effects for LWD Reaction

Relationship of *gca* effects of inbred lines with their*per se* performance

Significant positive but low magnitude of correlation between *per se* performance of the inbreds and their *gca* effects only for Kernel rows ear^{-1} (Figure 1-7 and Table 3), hence, suggested that *per se* performance of the lines is not a good indicator of their *gca* effects for any of the traits including LWD resistance.

The poor correlation between *per se* performance and *gca* effects of inbred line could be attributable to different sets of genes controlling *per se* performance and *gca* effects for target traits (Turner, 1953; Ai-Zhi& Zhang, 2012).

Significance of mean squares attributable to *gca* and *sca* (Table 1) provide evidence for the involvement of both additive genetic variance and dominance genetic variance for the expression of grain yield plant^{-1}, its attributing traits and LWD reaction.

Relationship of hybrid *per se* performance with sum of parental *gca* effects

Relatively high magnitude of correlation between sum of the parental *gca* effects with hybrid *per se* performance for all the traits (Figure 7-12 and Table 3), suggested that sum of the parental *gca* effects retained fairly higher predictability of hybrid *per se* performance.

It helps to predict hybrids performance based on their parental *gca* which is attributable to additive effect genes (Falconer & Mackay, 1996). Prediction of hybrid heterosis based on parental *gca* effects would save substantial resources as it enables the evaluation of only a few hybrids that are predicted to be most promising ones.

The utility of parental *gca* effects for predicting hybrid *per se* performance has also been reported by Schrag *et al.*, (2009), Sowmya & Gangappa (2018) and P. Roopa Sowjanya *et al.*, (2019).

From this study it is evident that the correlation between *per se* performance of hybrids and sum of parental *gca* effects will help in predicting the hybrids *per se* performance based on their parental *gca* effects for all the traits investigated including reaction to LWD infection, by selecting good inbreds which are having good *gca* effects for LWD reaction, grain yield and its component traits, we can expected to produce high yielding LWD resistant single cross hybrids. Hence, *gca* of parents can be used as a predictive tool for developing hybrids with superior *per se*, which in turn helps in reducing the use of input resources and enhances the breeding efficiency.

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