Electronic Journal of Plant Breeding, 8(3): 754-763 (September 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00116.8

Research Article

Genetic analysis of yield, yield related traits and amylose content in Boro rice (*Oryza sativa* L.) over environments

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(Received: 25 Nov 2016; Revised: 2017; Accepted: 20 Sep 2016)

Abstract
Nine boro rice genotypes were crossed in diallel mating design to study the inheritance of yield, yield related traits and amylose content over three seasons. Data from 36 F_1 and parents were analysed using Hayman's (1954) graphical approach. Majority of the traits studied revealed importance of over-dominance type of intra allelic interaction over the three seasons. The parents were scattered along the regression line indicating sufficient diversity among them for the traits.

Key words
Amylose content, Boro rice, Diallel analysis, Graphical approach, Yield

Introduction

Rice is one of the important crop along with wheat and maize. More than half of the world's population depends on rice for diet. In order to meet the food requirements of growing population a sound breeding programme is required aimed to increase in productivity. Adequate knowledge of gene actions for yield and quality traits is a prerequisite for success of any breeding programme in rice. Hayman's graphical approach provides information about the presence or absence of epistasis, degree of dominance, parental order of dominance, genetic diversity among parents and presence of Genotype x Environment interactions. Keeping in view the above mentioned facts, the present investigation was done to study the genetics of yield, yield related traits and amylose content in Boro rice using Hayman's graphical approach.

Materials and Methods

Nine diverse Boro rice genotypes were crossed in diallel mating design excluding reciprocals resulting in 36 F_1's. These crosses along with parents were grown in a randomized block design in three replications at Agricultural Research Farm, Banaras Hindu University, Varanasi, India during Boro-2014, Kharif-2015 and Boro-2015. The data were recorded from ten randomnly selected plants each from F_1s and parents from each replication. Gene actions were estimated by using graphical approach of diallel analysis (Jinks and Hayman, 1953; Hayman, 1954) with the help of statistical software Windostat v.9.2 (Windostat Services, Hyderabad, A.P., India).

Results and Discussion

The non-significant 't^2'values (Table 1) for all the traits except days to 50% flowering (Boro-2015 and *Kharif*-2015), days to maturity (in all the seasons), Effective tillers/plant (Boro-2014 and *Kharif*-2015), panicle length (Boro-2015), yield/plant (in all the seasons) and amylose content (in all the seasons) indicated the fulfilment of all the assumptions of diallel. Traits exhibiting significant 't^2' values suggested the lack of fulfillment of at least one of the assumptions. Non-significant deviation of regression coefficient 'b' from zero suggested the absence of linear relationship between variances and co-variances for most of the traits except days to 50% flowering (*Kharif*-2015), plant height (in all the seasons), effective tillers/plant (*Kharif*-2015), panicle length (Boro-2015), grains/panicle (Boro-2015 and *Kharif*-2015), yield/plant (Boro-2014), chlorophyll content (*Kharif*-2015) and amylose content (*Kharif*-2015). Traits such as plant height (Boro-2014 and Boro-2015), flag leaf width (Boro-2014), grains/panicle (Boro-2015 and *Kharif*-2015), 100 seed weight (*Kharif*-2015) and chlorophyll content (in all the seasons), showed non-significant deviation of 'b' from unity, which indicated absence of epistasis or inter-allelic interactions.

Regression coefficient were found non-significant for 100-kernel weight, grain width, panicle weight per plant, total weight per plant and mean panicle weight which indicated the fulfillment of all the assumptions of diallel, reported by Murai and Kinoshita (1986) which is similar to the findings of present study. Iftekharuddaula *et al*. (2009) reported non-significant estimates of 't^2- test' for primary branch length, secondary branch length, primary branch/panicle, unfilled grains/primary branch, filled grains/secondary branch and unfilled grains/secondary branch in rice. Though the estimatesof t^2 was significant for secondary branch/panicle and filled grains/primary branch. Presence of epistasis may be one of the reasons for significance of 't^2' estimates.
Vr-Wr graphs were plotted only for those traits which exhibited significant deviation of regression

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coefficient ‘b’ from zero, irrespective of significance of ‘t^2’ or deviation of ‘b’ from unity. Deviation of regression coefficient ‘b’ from zero was non-significant in boro-2014 and boro-2015 but it was significant for kharif-2015. Therefore Vr-Wr graph was plotted only for kharif-2015 (Fig.1) which revealed over-dominance for days to 50% flowering. Most of the parental points fell away from the observed regression line which suggested the presence of G x E interaction. The scattered array points on the regression line indicated diversity among parents. Gautam exhibited greater proportion of dominant alleles as it fell close to the origin and HUR 36 revealed greater portion of recessive alleles due to farther distance from the origin. Chaturvedi *et al*. (2015) reported over dominance in case of days to 50% flowering as the regression line interseted the Wr axis below the origin in their study which supports the present finding. However, Dwivedi *et al*. (1980) reported partial dominance in inheritance of the trait days to 50% flowering in rice.

Significant deviation of regression coefficient ‘b’ from zero was observed in all seasons for plant height. Over-dominance was observed in all the three seasons (boro-2014, boro-2015 and kharif-2015) as regression line intersected the Wr-axis below the origin (Fig.2, Fig.3 and Fig.4). The scattered array points on the regression line indicated diversity among the parents in all the three seasons. In all the three seasons, IR 64 showed greater proportion of dominant alleles whereas HUR 36 showed greater proportion of recessive alleles. Most of the parental points fell away from the regression line which revealed high G x E interaction for the trait. Similar to present finding, Raju *et al*. (2011) and Chaturvedi *et al*. (2015) also reported over-dominance for plant height which is an agreement with present findings. However, Mahmood *et al*. (2004) reported partial dominance in inheritance of this trait.

Over-dominance was observed for the trait effective tillers/plant as the regression line intersected below the origin on Wr-axis in kharif-2015 (Fig.5). However, in boro-2014 and boro-2015, regression coefficient ‘b’ did not show significant deviation from zero and therefore Vr-Wr graph was plotted only for kharif season. Raju *et al*. (2011) reported that for ear bearing tillers per plant, the deviations of regression coefficient from zero were not significant. Hence, Vr-Wr graph were not plotted. This is similar to present findings for boro-2014 and boro-2015. The scattered parental points on the regression line indicated diversity among parents. Jaya revealed highest proportion of dominant alleles as it lies near the origin whereas IR 8 revealed highest proportion of recessive alleles. Presence of G x E interaction was observed for the trait as most of the parental points were away from the regression line. Xu and Shen (1991) reported both partial dominance and over dominance for inheritance of tillers per plant in rice. However, Mahmood *et al*. (2004) and Chaturvedi *et al.* (2015) reported partial dominance for inheritance of this trait.

For panicle length, the regression coefficient ‘b’ did not show significant deviation from zero in boro-2014 and kharif-2015, indicating non-linear relationship between Vr and Wr. Thus graphical analysis was not conducted for this trait. In boro-2015, there was sufficient departure of ‘b’ from zero and over-dominance was observed for this trait (Fig.6). Over-dominance for panicle length has also been reported by Raju *et al*. (2011) and Chaturvedi *et al.* (2015) in case of rice. The scattered parental points over the regression line revealed high G x E interaction. A greater proportion of dominant alleles for the trait were observed in parental line Gautam whereas IR 36 showed greater proportion of recessive alleles. However, Mahmood *et al*. (2004) reported complete dominance and Akram *et al*. (2007) reported partial dominance for inheritance of this trait.

Significant deviation of regression coefficient ‘b’ from zero was observed in all seasons for grains/panicle except boro-2014. Over-dominance was observed in boro-2015 and kharif-2015 as regression line intersected the Wr- axis below the origin (Fig.7 and Fig.8). In both the season, most of the parents clustered near the origin, indicating higher proportion of dominant alleles for this trait. HUR 36 revealed greater proportion of recessive alleles for the trait in both the season. Presence of G x E was observed as parental points were situated away from the regression line. However, Akram *et al*. (2007) and Chaturvedi *et al*. (2015) reported partial dominance for grains/panicle in rice.

Deviation of regression coefficient ‘b’ from zero was non-significant in boro-2015 and kharif-2015 but was significant for boro-2014 (Fig.9). Therefore Vr-Wr graph was plotted only for boro-2014. The regression line intersected the Wr-axis below the origin which revealed over-dominance for yield/plant. Ilieva *et al*. (2013) and Chaturvedi *et al*. (2015) also reported over-dominance for the trait which is in agreement with present finding. Most of the parental points fell away from the observed regression line and suggested the presence of G x E interaction. Parental line HUR 36 and HUR 105 exhibited greater proportion of dominant alleles whereas MTU 1010 exhibited greater proportion of recessive alleles for the trait. However, Akram *et al*. (2007) reported partial dominance for inheritance of the trait.

Intersection of regression line below the origin on Wr-axis clearly indicated the presence of over-dominance for chlorophyll content in kharif-2015 (Fig.10). The regression coefficient ‘b’ did not show significant deviation from zero in boro-2014 and boro-2015 so graphical analysis was not conducted. The scattered points over the regression line revealed diversity among parents. Occurrence of parental points away from the origin indicated high influence of G x E interaction. Parental lines MTU 1010, Gautam, IR 36 and Krishna Hamsa exhibited higher proportion of dominant alleles for the trait whereas HUR 36, HUR 105, IR 8, IR 64 and Jaya exhibited greater proportion of recessive alleles for the trait.

For amylose content, the regression coefficient ‘b’ did not show significant deviation from zero in boro-2014 and boro-2015, indicating non-linear relationship between Vr and Wr. Thus graphical analysis was not conducted for this trait in boro-2014 and boro-2015. In kharif-2015, there was sufficient departure of ‘b’ from zero and over-dominance was observed (Fig.11). Occurrence of parental points away from the regression line indicated high G x E interaction for the trait. Among parental lines, IR 36 showed highest proportion of dominant alleles for the trait whereas IR 64 exhibited highest proportion of recessive alleles for the trait. Deviation of regression coefficient ‘b’ from unity indicated presence of epistasis for this trait in all the three seasons (boro-2014, boro-2015 and kharif-2015). Kuo *et.al.* (1995), Sharma and Mani (1998) reported non additive gene action for inheritance of the trait. However, partial dominance of high amylose content in F_1 generation was reported by Kahlon (1964).

Graphical analysis revealed importance of over dominance type of intra allelic interaction over the three seasons. Since, over-dominance type of gene action was observed for majority of the traits studied, it would be worthwhile to examine these in the development of hybrids.

Acknowledgement
The first author is grateful to the Department of Science and Technology, New Delhi, India for financial assistance as INSPIRE Fellowship and Department of Genetics and Plant Breeding, BHU for providing facilities for conduct of experiments during the course of present study.

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Table 1. Estimates of "t^2" and "b" for 9 x 9 diallel analysis for yield traits and amylose content in Boro rice over seasons

Traits	"t^2"			b(Slope) ± SE(b)			H_0: b = 0			H_0 : b =1		
	Boro-2014	**Boro-2015**	***Kharif*-2015**	**Boro-2014**	**Boro-2015**	***Kharif*-2015**	**Boro-2014**	**Boro-2015**	***Kharif*-2015**	**Boro-2014**	**Boro-2015**	***Kharif*-2015**
DTF	3.433	18.697**	9.265**	0.343 ± 0.178	0.151 ± 0.104	0.338 ± 0.127	NS	NS	*	**	**	**
DTM	6.019*	23.550**	10.843**	0.248 ± 0.156	0.144 ± 0.094	0.290 ± 0.123	NS	NS	NS	**	**	**
PH	1.241	0.111	3.598	0.595±0.184	0.743 ±0.210	0.421 ± 0.166	*	**	*	NS	NS	*
ET/P	10.647**	2.307	45.517**	0.169 ± 0.131	0.389 ± 0.193	0.328 ± 0.064	NS	NS	**	**	*	**
PL	0.355	15.136**	2.374	-0.220 ± 0.293	-0.265 ± 0.109	0.040 ± 0.217	NS	*	NS	**	**	**
FL	1.484	2.640	0.123	0.366 ± 0.218	0.015 ± 0.211	-0.133 ± 0.328	NS	NS	NS	*	**	*
FW	0.054	2.738	0.419	0.324 ± 0.326	0.042 ± 0.209	-0.013 ± 0.297	NS	NS	NS	NS	**	*
G/P	1.404	0.358	0.432	0.280 ± 0.231	0.592 ± 0.231	0.804 ± 0.150	NS	*	**	*	NS	NS
100SW	1.463	0.371	0.001	0.156 ± 0.239	-0.112 ± 0.299	0.564 ± 0.308	NS	NS	NS	**	**	NS
Y/P	37.285**	66.035**	38.756**	0.22 ±0.075	0.010 ± 0.060	0.035 ± 0.077	*	NS	NS	**	**	**
CC	0.355	1.253	2.093	0.711 ± 0.364	0.785 ± 0.443	1.094 ± 0.328	NS	NS	*	NS	NS	NS
AC	4.609*	14.382**	10.036**	0.009 ± 0.180	-0.026 ± 0.119	0.339 ± 0.123	NS	NS	*	**	**	**

*$p \leq 0.05$; **$p \leq 0.01$;***$p \leq 0.001$; NS- Non Significant; DTF – Days to 50% flowering; DTM – Days to maturity; PH- Plant height; ET/P – Effective tillers/plant; PL- Panicle length; FL – Flag leaf length; FW- Flag leaf width; G/P-Grains/panicle; 100SW- 100 seed weight; Y/P- Yield/plant; CC- Chlorophyll content; AC- Amylose content

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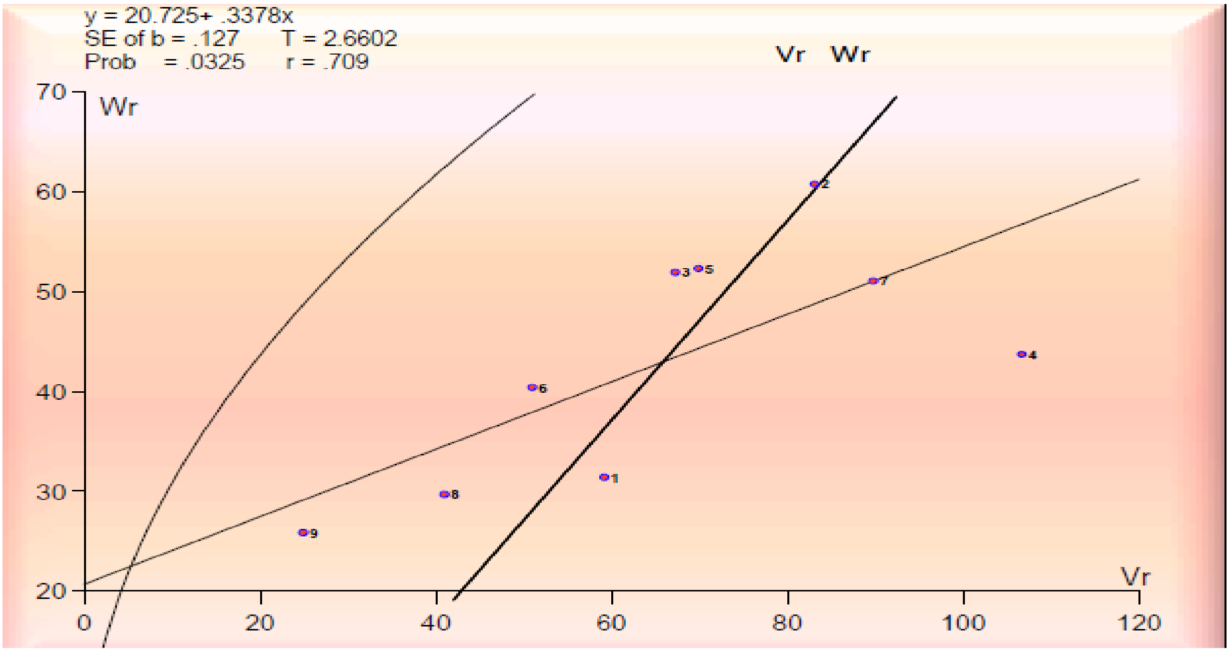

Fig. 1: Vr-Wr graph for days to 50% flowering in *Kharif*-2015

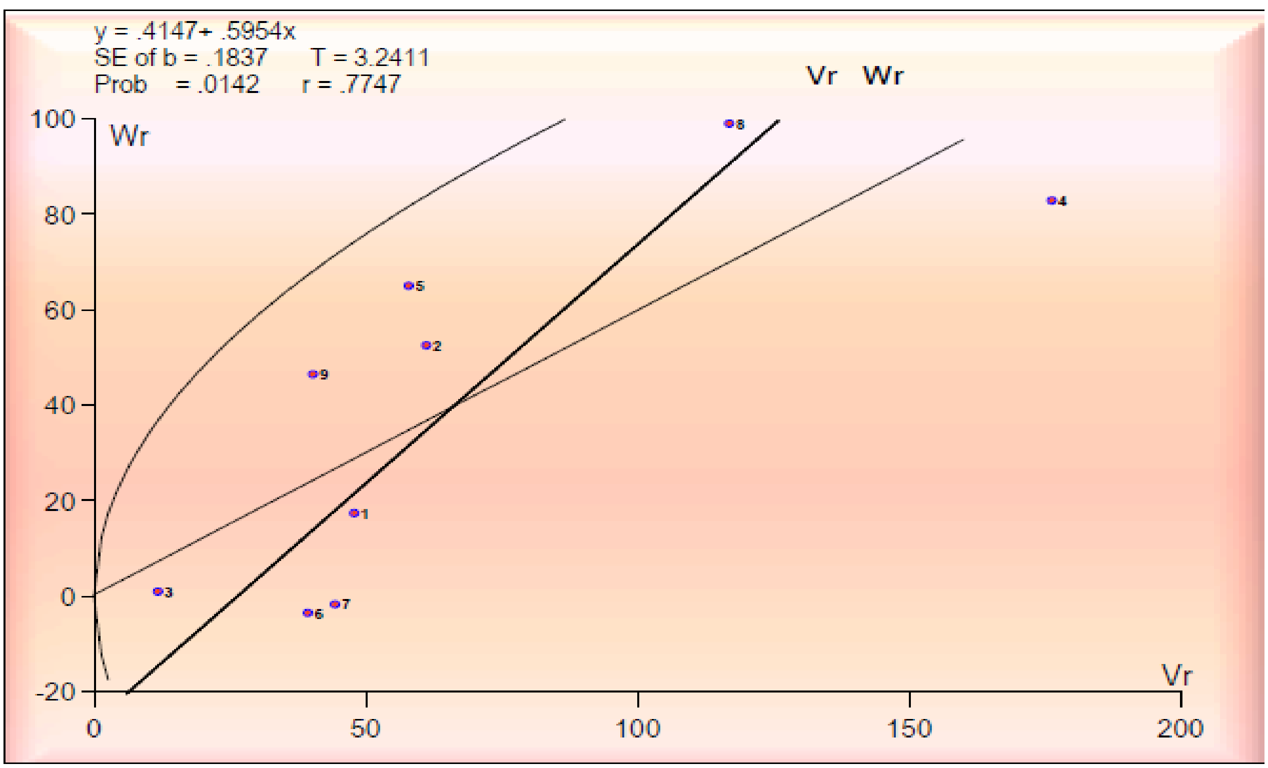

Fig. 2: Vr-Wr graph for plant height in Boro-2014

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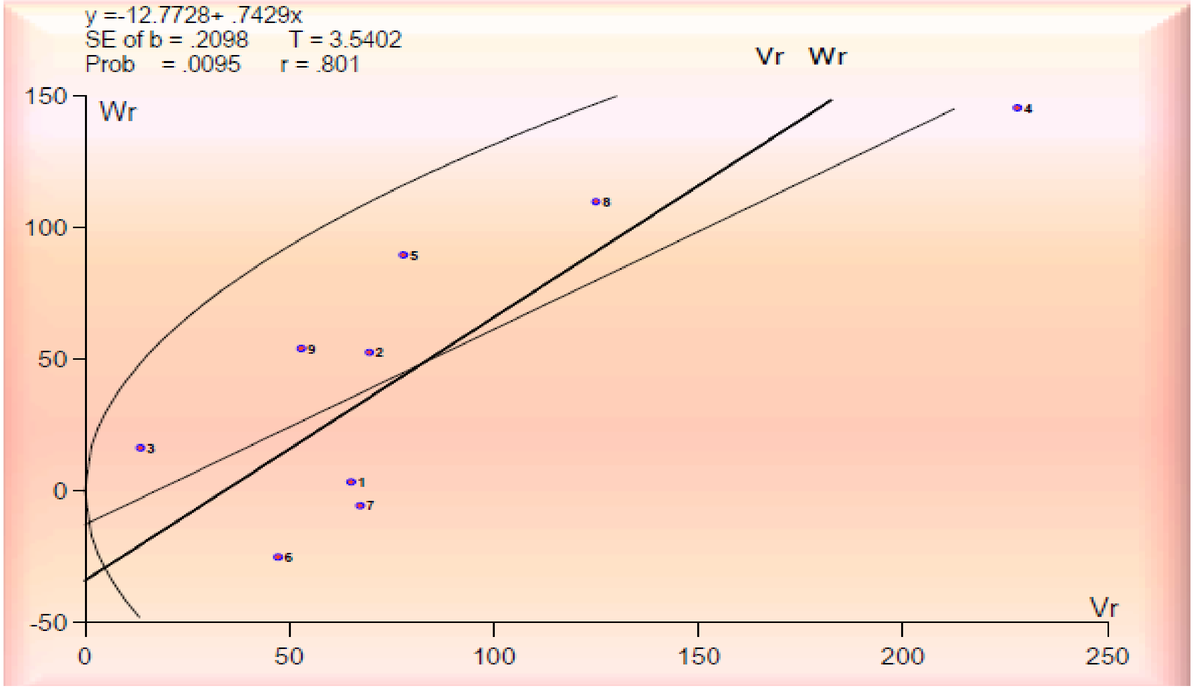

Fig. 3: Vr-Wr graph for plant height in Boro-2015

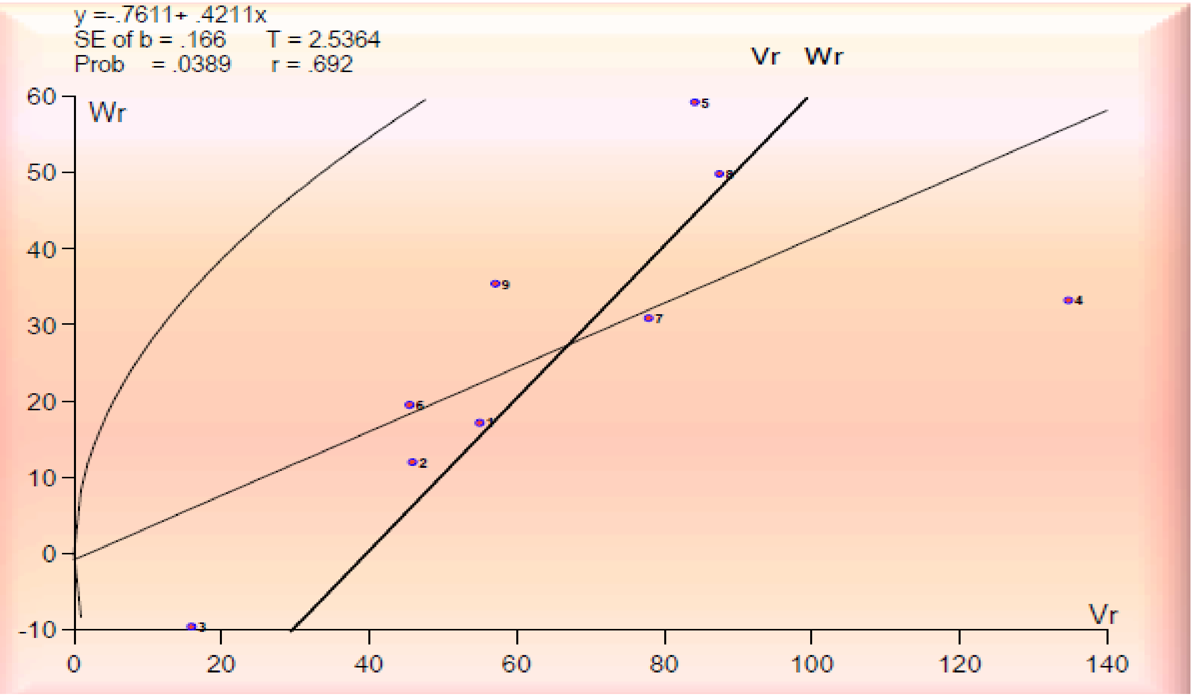

Fig. 4: Vr-Wr graph for plant height in *Kharif*-2015

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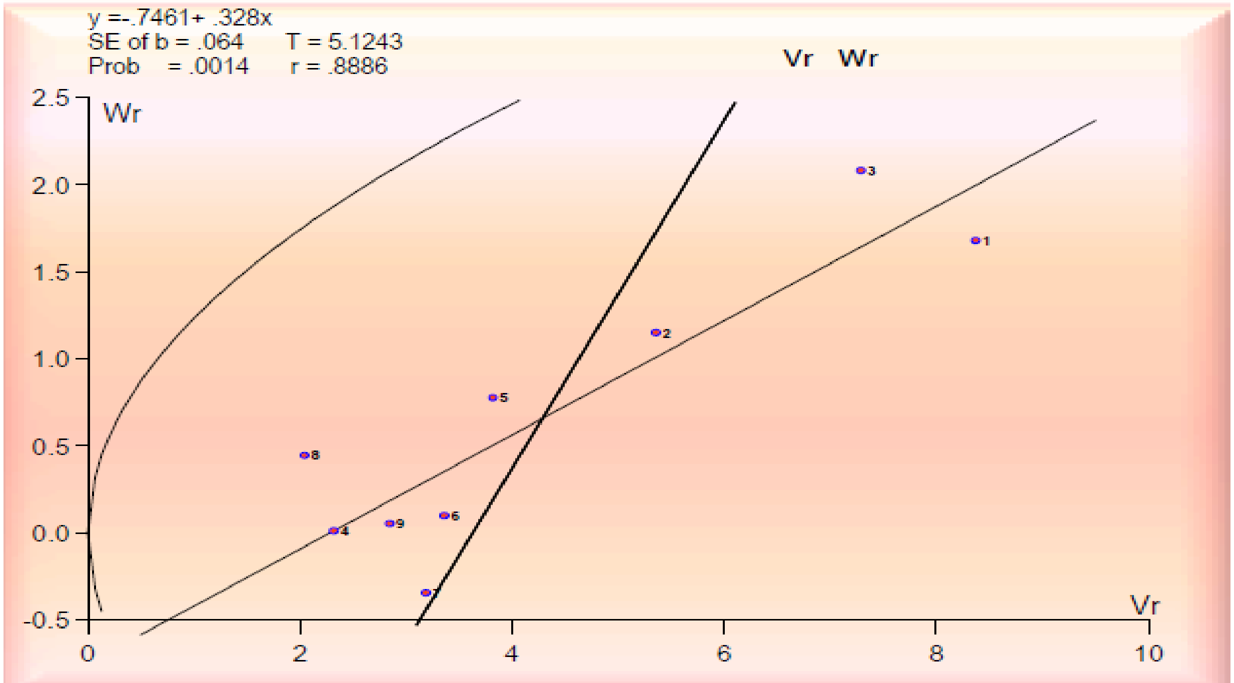

Fig. 5: Vr-Wr graph for effective tillers/plant in *Kharif*-2015

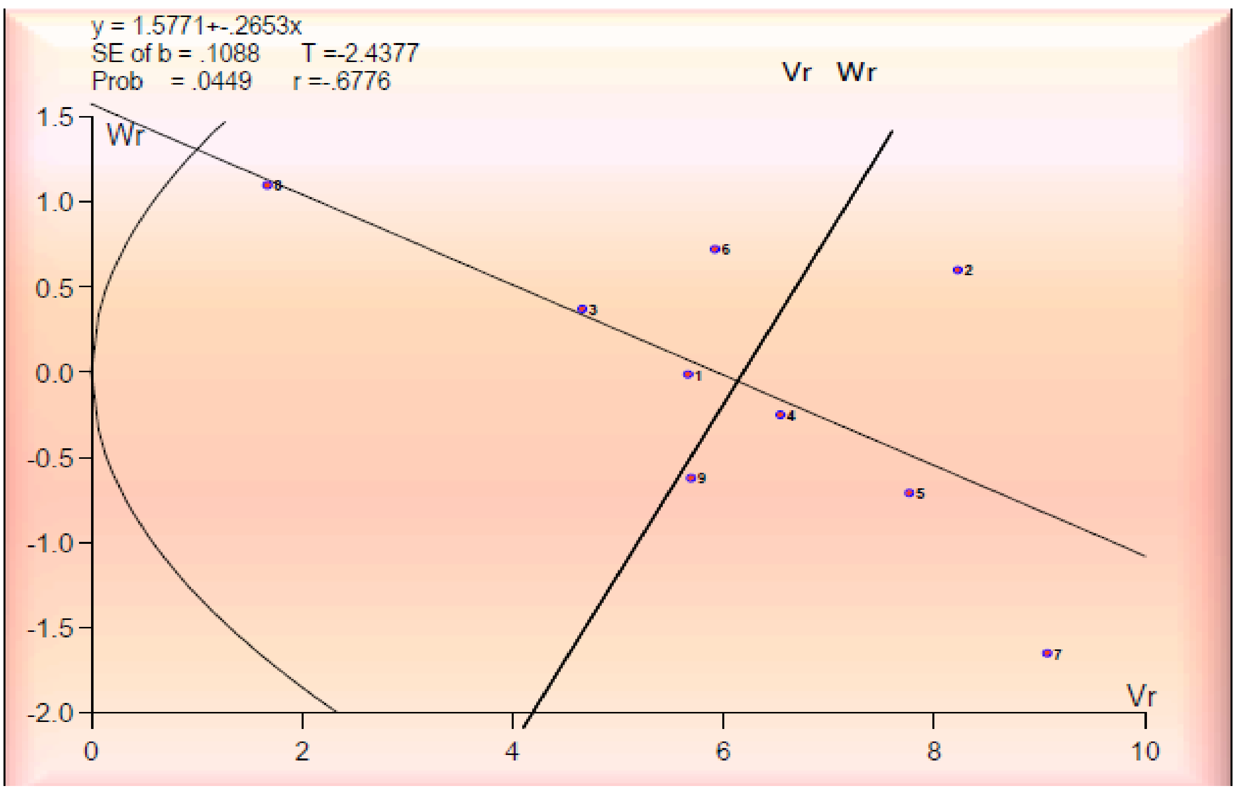

Fig. 6: Vr-Wr graph for panicle length in Boro-2015

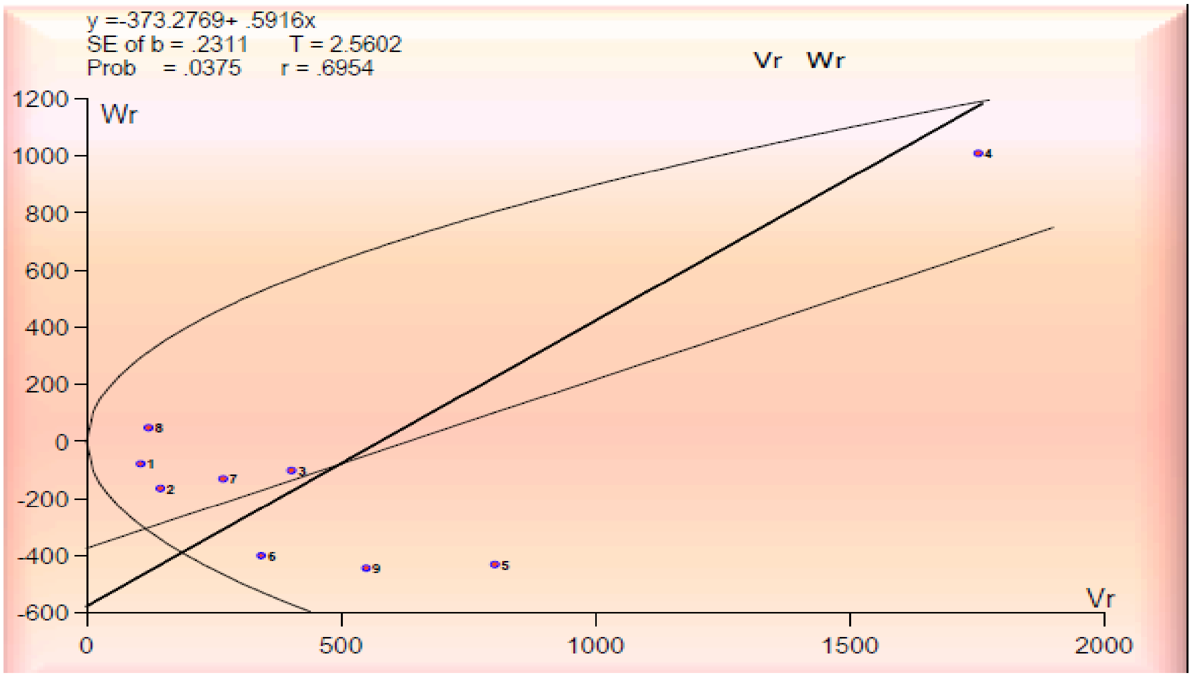

Fig. 7: Vr-Wr graph for grains/panicle in Boro-2015

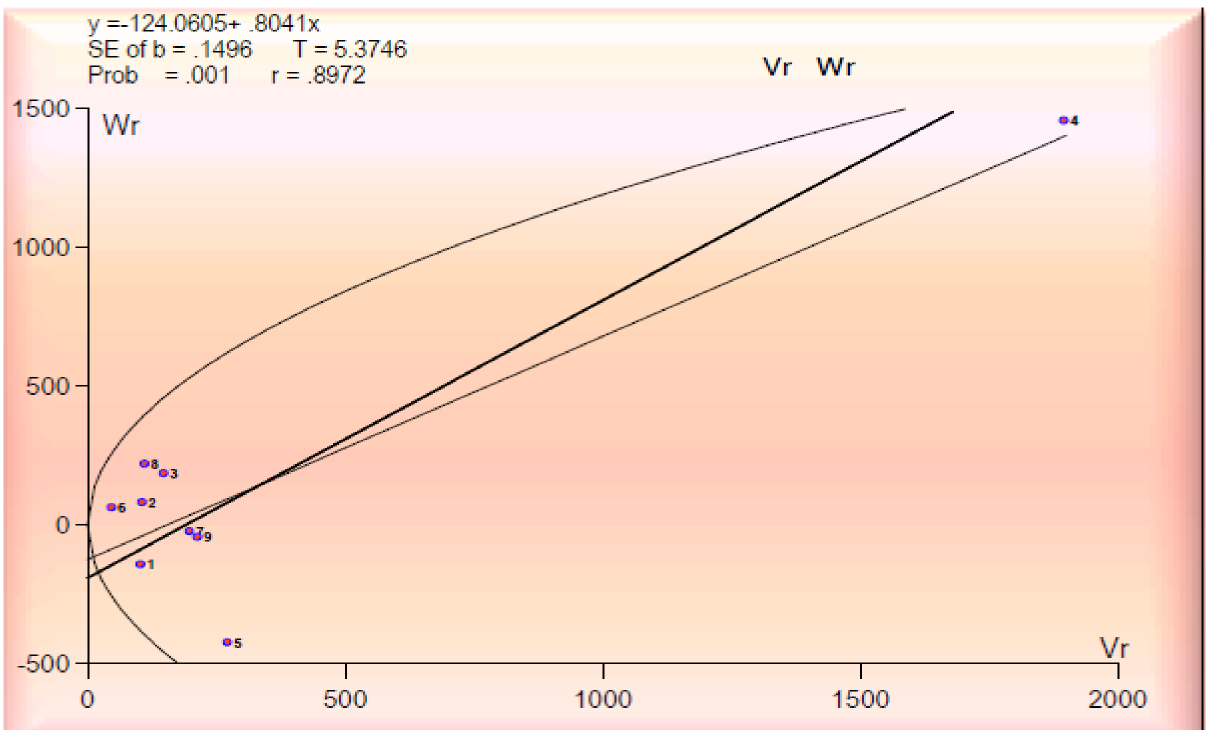

Fig. 8: Vr-Wr graph for grains/panicle in *Kharif*-2015

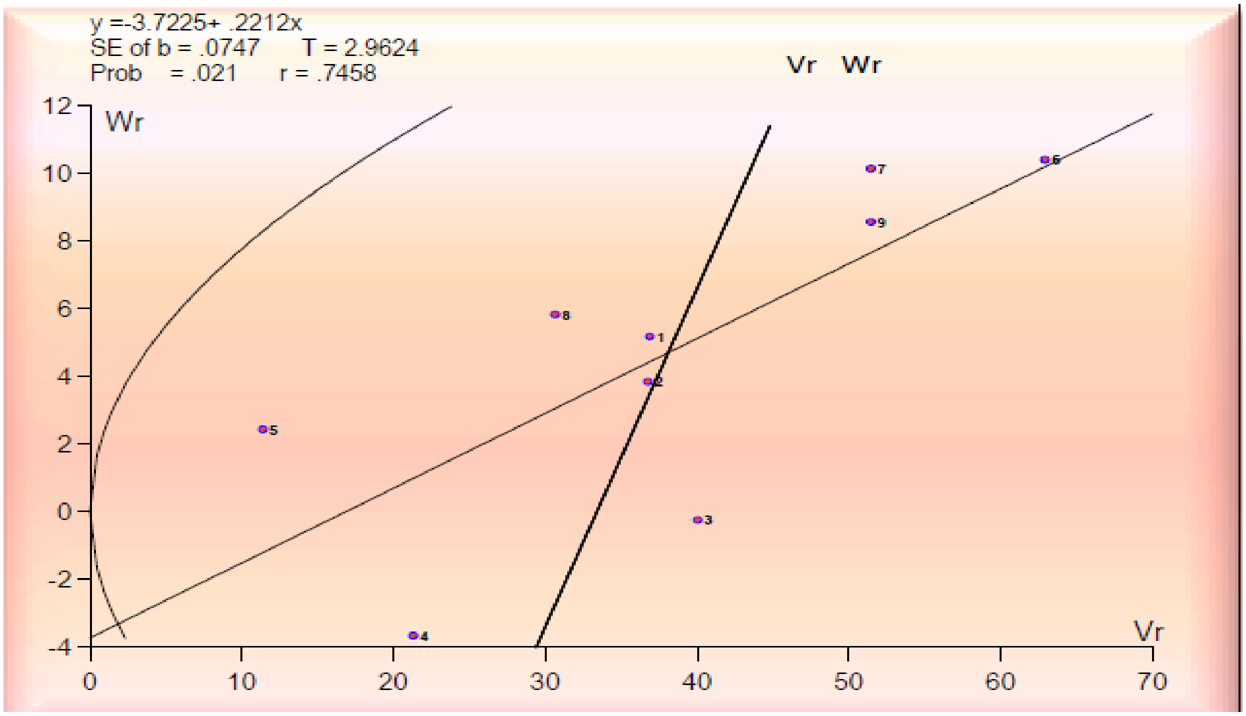

Fig. 9: Vr-Wr graph for yield/plant in Boro-2014

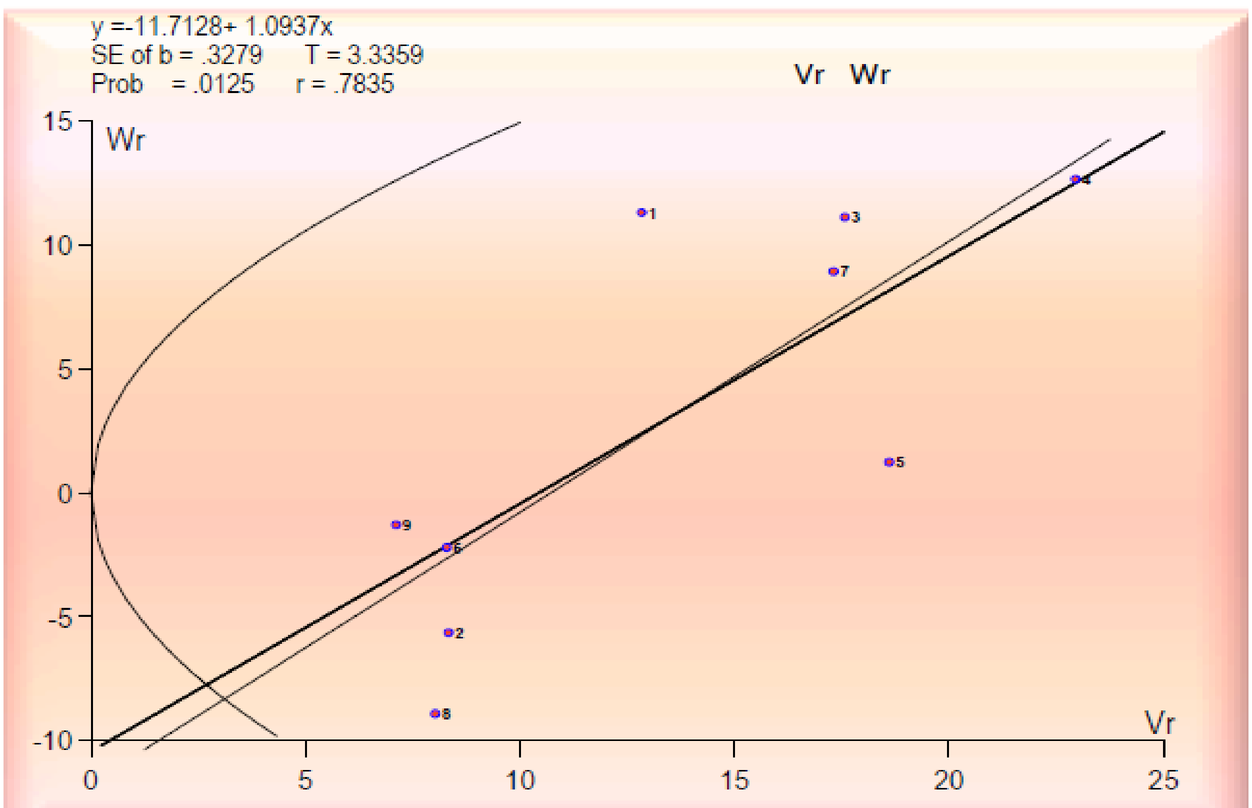

Fig. 10: Vr-Wr graph for Chlorophyll content in *Kharif*-2015

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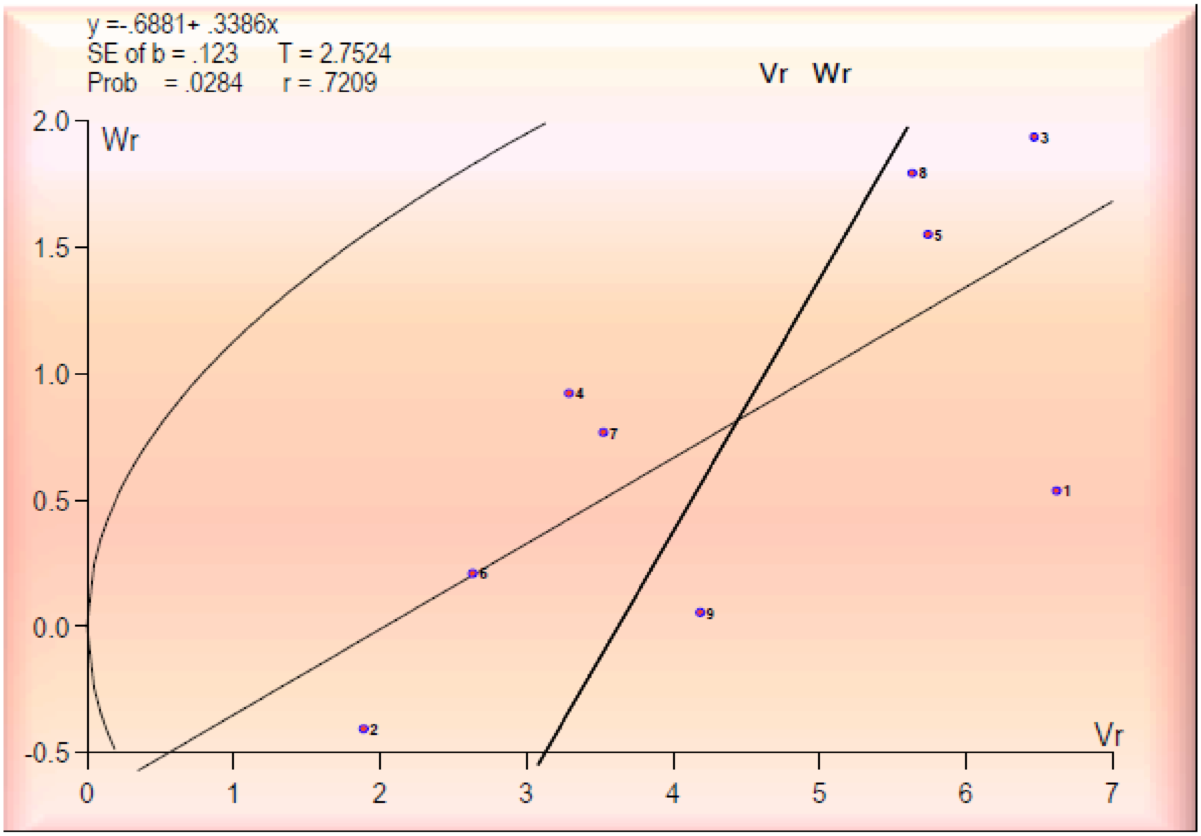

Fig. 11: Vr-Wr graph for amylose content in *Kharif*-2015

1. IR 8; 2. IR 36; 3. IR 64; 4. HUR 36; 5. HUR 105; 6. MTU 1010; 7. Jaya; 8. Krishna Hamsa; 9. Gautam

______________Expected regression line______________Observed regression line