Estimation of Combining Ability and Gene Action in Half Diallel Crosses of Bread Wheat (*Triticum aestivum* L.) genotypes.

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ABSTRACT

The study evaluated 55 wheat treatments, including 46 F1 hybrids, 10 parental lines, and one standard check variety, using a diallel mating design during the 2019-2020 rabi season at the Research Farm of BRD PG College, Deoria, Uttar Pradesh. The parental lines included LAWL-1, HUW-206, Allahabad local, Shriram-303, RAJ 4120, PUSA 2733, RAJ 4037, PBW 243, DH 3171, and PBW 502. Analysis of variance (ANOVA) revealed significant genetic variability among the genotypes for all traits except the harvest index, demonstrating both genetic diversity and treatment effects. Key traits such as plant height, flowering days, maturity days, grains per spike, and seed germination varied significantly among parents and hybrids, indicating hybrid vigor. General Combining Ability (GCA) analysis highlighted LAWL-1 as a strong combiner for biological yield, harvest index, and gluten content, while PBW 502 was effective in reducing plant height. Specific Combining Ability (SCA) analysis identified promising hybrids like LAWL-1 x DH 3171 and RAJ 4120 x PBW 502, which showed significant improvements in grain yield, plant height, and harvest index. These findings emphasize the importance of selecting appropriate parents and hybrid combinations to enhance specific traits and support wheat breeding programs focused on improved yield, early flowering, and efficient thresh ability.

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Keywords: Wheat genotypes, Diallel, Combining ability, Cross combination

1. INTRODUCTION

Wheat is the principal food crop in most areas of the world and also occupies prominent position in Indian agriculture after rice. It is nutritionally important cereal essential for the food security, poverty alleviation and for livelihoods (Sharma & Duveiller 2004). It is widely cultivated as staple food crop among cereals and is contributing about 30% to the food basket of the country (Hassani *et al*., 2016). Different components of grain yield often exhibit varying degree of association with grain yield as well as among themselves. The exploitation of heterosis is one of the breeding strategies to enhance the productivity. Combining ability analysis enables the breeder in his task of selecting the parents. It also provides the vital and necessary information on the nature of gene action governing the expression of the character in question and thus helps in deciding upon the future breeding strategy. This can be of immense help to plant breeders in choosing desirable genotypes for a breeding programme to provide valuable information regarding cross combinations to be exploited commercially. Assessing the performance and compatibility of genotypes is crucial for optimizing hybridization success. Techniques like diallel, partial diallel, and line x tester offer different methods to estimate breeding requirements. In particular, the line x tester mating design allows for the evaluation of specific combining ability (SCA) for individual crosses and general combining ability (GCA) for lines and testers, providing valuable insights for improving breeding strategies.

2. MATERIALS AND METHODS

The experimental materials for this study consisted of 55 wheat treatments, including 46 F1 hybrids, 10 parental lines and one standard variety used as a check. The parental lines viz.,

LAWL-1 , HUW-206, Allahabad local, Shriram-303, RAJ 4120, PUSA 2733, RAJ 4037, PBW 243, DH 3171 and PBW 502. The experimental hybrids were developed using a diallel mating design during the 2019-2020 rabi season at the Research Farm of BRD PG College, Deoria (Affiliated with DDU Gorakhpur University, Uttar Pradesh).

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3. STATISTICAL ANALYSIS

The analysis of variance (ANOVA) was conducted following Hayman (1954), and combining ability for the line x tester design was analyzed using Kempthorne's method (1957). Data were processed in R using the Agricolae package (Version 1.3-5). Combining ability for each trait was calculated based on Hayes *et al.* (1955).

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4. RESULTS AND DISCUSSION

4.1 Analysis of Variance (ANOVA)

The analysis of variance (ANOVA) was conducted to assess the differences among parents and hybrids across thirteen traits, with results detailed in Table 1. Significant mean squares were found for all traits except the harvest index, indicating notable genetic variability among the genotypes tested, essential for breeding superior varieties (Smith *et al*., 2023). In the study of 19 traits for wheat crosses (F1s) and their parent lines, significant variations were identified across different sources, highlighting both genetic diversity and the impact of treatments. Replications exhibited considerable variances across several traits, suggesting environmental influences. Treatments revealed substantial differences across almost all traits, underscoring the importance of treatment effects on genetic expression. Key traits such as Plant Height (PH), Days to 50% Flowering (DFF), Date of Maturity (DM), Grains per Spike (GS), and Seed Germination (SG) showed significant variability among parent lines, emphasizing their genetic diversity (Lee *et al*.,

2021). Similarly, hybrids exhibited significant differences across multiple traits, including PH, DFF, DM, Effective Tillers per Plant (ETP), Spike Length (SL), Spikelets per Spike (SS), GS, Test Weight (TW), Grain Yield per Plant (GYP), Biological Yield per Plant (BYP), Flag Leaf Area (FLA), Seedling Vigour (SV), Free Threshability (FT), Gluten Content (GC), and Harvest Index (HI), indicating the presence of hybrid vigor (Patel et al., 2021). Comparisons between parents and hybrids demonstrated significant genetic differences in numerous traits, such as PH, DM, SL, SS, GS, TW, GYP, FLA, SG, FT, GC, and HI, highlighting the distinct genetic potential of hybrids over parent lines (Jones *et al*., 2022). These findings suggest that both genetic and treatment-induced variability play a crucial role in wheat breeding programs, enabling the enhancement of specific traits through strategic crossbreeding and selection (Verma & Gupta, 2021).

4.2. Combining ability effects

4.2.1 General Combining ability effects (GCA)

The success of any breeding program relies heavily on the choice of parents and the appropriate breeding procedures. Combining ability is a crucial tool for distinguishing between good and poor combiners, aiding in the selection of suitable parental lines for hybridization to exploit heterosis. General Combining Ability (GCA) effects provide valuable insights into the overall performance of parent lines across multiple traits. For Plant Height (PH), GCA effects ranged from -2.78 in PBW 502 to 3.07* in RAJ 4120, with RAJ 4120 showing significant positive effects, while PBW 502 exhibited a strong negative effect, making it ideal for reducing plant height. In terms of Days to 50% Flowering (DFF), HUW-206 demonstrated a significant negative effect (-1.94*), suggesting earlier flowering, whereas LAWL-1 had a positive effect (2.10*), indicating delayed flowering. For Date of Maturity (DM), GCA values ranged from -1.41* in DH 3171, promoting early maturity, to 0.42* in RAJ 4120 and LAWL-1, indicating a tendency for later

maturity. Effective Tillers per Plant (ETP) showed positive GCA effects of 0.61* in RAJ 4120, while Shriram-303 had negative effects (-0.34). Spike Length (SL) exhibited a positive GCA effect of 0.33* in PBW 502, whereas RAJ 4120 showed a negative effect (-0.23). For Spikelets per Spike (SS), the range extended from -0.74* in RAJ 4037 to 0.63* in LAWL-1, demonstrating LAWL-1's superior combining ability for this trait.

Grains per Spike (GS) ranged from a negative effect of -1.21 in PBW 502 to a positive effect of 1.84* in LAWL-1, reflecting the latter's potential to enhance grain production. For Grain Weight per Spike (GWS), RAJ 4120 showed a positive effect (0.19*), while LAWL-1 had a negative effect (-0.24*). Test Weight (TW) followed a similar trend, with RAJ 4120 showing a positive GCA effect of 0.65*, whereas LAWL-1 exhibited negative effects (-0.98*). Grain Yield per Plant (GYP) demonstrated positive effects in HUW-206 (0.48*) and negative effects in RAJ 4120 (-0.17*). In Biological Yield per Plant (BYP), LAWL-1 showed significant positive effects (1.75*), while HUW-206 had a notable negative effect (-1.44). Flag Leaf Area (FLA) ranged from -1.95* in Allahabad local to 1.28* in PBW 502, indicating PBW 502's advantage in this trait. Seed Moisture Content (SM) and Seed Density (SD) exhibited positive GCA effects in RAJ 4120 (0.19*) and LAWL-1 (0.32*), respectively, while PBW 502 and RAJ 4037 showed negative effects for these traits.

For Seed Germination (SG), the effects ranged from -4.63* in RAJ 4120 to 0.91* in PBW 502, suggesting PBW 502's superior performance in germination. Seedling Vigour (SV) showed positive GCA effects in HUW-206 (0.49*), whereas Allahabad local exhibited negative effects (-0.58*). Free Threshability (FT) varied from -13.74** in PUSA 2733 to 19.64** in LAWL-1, indicating significant positive performance in LAWL-1. Gluten Content (GC) also showed variability, with LAWL-1 achieving a high positive effect (21.69**) and PUSA 2733 exhibiting

negative effects (-5.91**). Harvest Index (HI) demonstrated a range from -1.98* in RAJ 4120 to 2.83* in LAWL-1, further supporting LAWL-1's potential for improvement in this trait.

4.2.2 Specific Combining ability effects (SCA)

The Specific Combining Ability (SCA) effects provided additional insights into the performance of specific hybrid combinations. For Plant Height (PH), the SCA effects ranged from -8.64 in LAWL-1 x PUSA 2733 to 10.58 in LAWL-1 x DH 3171, indicating significant positive effects in the latter cross. In Days to 50% Flowering (DFF), Allahabad local x PUSA 2733 showed a strong negative effect (-6.39**), indicating early flowering, while LAWL-1 x RAJ 4037 had a positive effect (5.31**). The SCA effects for Date of Maturity (DM) ranged from -4.07** in Allahabad local x PUSA 2733 to 3.09** in LAWL-1 x RAJ 4037, demonstrating variability in maturity. Effective Tillers per Plant (ETP) showed positive effects in the cross Allahabad local x PBW 243 (1.36**).

For Spike Length (SL), Shriram-303 x RAJ 4120 showed a positive effect (1.48), while for Spikelets per Spike (SS), LAWL-1 x DH 3171 exhibited the highest positive effect (3.65**). Grains per Spike (GS) had the highest positive effect in HUW-206 x Allahabad local (3.75**), and Grain Weight per Spike (GWS) showed a positive effect in LAWL-1 x HUW-206 (2.27**). Test Weight (TW) was positively impacted in the cross Shriram-303 x PBW 502 (2.82**). Grain Yield per Plant (GYP) demonstrated the highest positive effect in RAJ 4120 x PBW 502 (2.46**), while Biological Yield per Plant (BYP) showed positive effects in Allahabad local x PBW 502 (5.39**).

Flag Leaf Area (FLA) was significantly improved in RAJ 4037 x DH 3171 (6.02**), and Seed Moisture Content (SM) was positively affected in Allahabad local x PUSA 2733 (1.02**). Seed Density (SD) exhibited positive effects in Allahabad local x Shriram-303 (0.67). For Seed Germination (SG), the cross RAJ 4120 x PBW 243 showed the highest positive effect (6.14**), and Seedling Vigour (SV) was positively influenced by LAWL-1 x RAJ 4037 (2.37**). Free Threshability (FT) ranged from a significant negative effect of -22.32** in LAWL-1 x RAJ 4120 to a positive effect of 19.74** in LAWL-1 x PUSA 2733. Gluten Content (GC) exhibited the highest positive effect in RAJ 4037 x DH 3171 (21.90**). Finally, Harvest Index (HI) showed significant positive effects in LAWL-1 x DH 3171 (10.65**), further supporting the utility of these crosses in enhancing wheat traits. These results emphasize the importance of both GCA and SCA

in selecting superior parental lines and cross combinations, which can contribute to the development of improved wheat varieties through targeted breeding programs.

CONCLUSION

The analysis revealed significant genetic variability across most traits, except the harvest index, demonstrating strong potential for breeding superior wheat varieties. Hybrids exhibited notable improvements in traits such as plant height, grain yield, spike length, and test weight, reflecting hybrid vigor and genetic advantages over parent lines. General Combining Ability (GCA) analysis identified LAWL-1 as a strong performer for key traits like gluten content, biological yield, and harvest index, while PBW 502 showed negative GCA for plant height, making it ideal for height reduction. Specific Combining Ability (SCA) effects highlighted promising crosses, such as LAWL-1 x DH 3171 and RAJ 4120 x PBW 502, which demonstrated high potential for improving grain yield, plant height, and harvest index. These findings emphasize the importance of strategic parent selection and hybrid combinations to optimize specific traits, supporting more efficient breeding programs aimed at enhancing grain production, early flowering, and improved threshability.

Ethical issues: None.

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Table: 1 Analysis of variance for yield and its contributing characters

Traits	Replications (df=2)	Treatments (df=55)	Parents (df=10)	Hybrids (df=44)	Parents vs Hybrids (df=1)	Error (df=110)
Plant height (PH)	79.07	95.51**	102.53**	94.87**	59.76**	20.43
Days to 50 % flowering (DFF)	49.68	23.44**	15.05**	24.83**	37.92	16.30
Date of maturity (DM)	179.50	16.49**	13.81**	7.06**	455.41**	4.58
Effectiv tiller/ plant (ETP)	17.57	1.78	1.03	12.37**	26.99	1.10
Spike length (SL)	71.89	2.97	2.50	11.81**	58.38**	1.23
Spikelets/Spike (SS)	9.62	14.71**	6.65	5.34**	499.42**	4.00
Grains/Spike (GS)	31.97	17.34**	20.32**	15.46**	73.61**	6.25
Grain weight/spike (GWS)	11.66	0.38	0.12	0.44	0.29	0.38
Test weight (TW)	55.08	10.96**	5.06	6.741**	250.06**	9.68
Grain yield/ plant (GYP)	32.59	8.03**	1.18	13.20**	82.51**	3.55
Biological yield (BYP)	92.98	21.39**	33.37	19.12**	13.73	14.53
Flag leaf Area (FLA)	61.44	76.54**	49.29**	59.45**	173.88**	41.85
Seed moisture content	0.07	0.73	0.78	0.74	0.10	0.99
Seed density (SD)	0.10	0.28	0.17	0.29	1.08	0.18
Seed germination (SG)	36.39	56.72**	306.65**	2.56	190.40**	60.80
Seedling vigour (SV)	40.88	6.19**	5.13	6.55**	4.03	10.12
Free thresability (FT)	26.17	87.11**	257.29**	164.67**	342.51**	40.14
Gluten Content (GC)	253.32	309.51**	4.53	194.56**	512.16**	640.44
Harvest Index (HI)	160.08	127.98**	118.79	78.40	392.50**	64.82

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Give details below the table

Table: 2. Estimate of general combining ability (GCA) effects

Parents	PH	DFF	DM	ETP	SL	SS
LAWL-1	0.03	2.10*	0.42*	-0.11	0.20	0.63*
HUW-206	2.90*	-1.94*	0.42*	0.01	-0.09	0.11
Allahabad local	1.57*	0.04	0.14	-0.01	-0.03	0.39
Shriram-303	-2.77*	1.12	0.22	-0.34	-0.17	-0.03
RAJ 4120	3.07*	0.57	0.42	0.61*	-0.23	0.16
PUSA 2733	-1.17	1.19**	0.08	0.29*	0.04	-0.11
RAJ 4037	0.56	-0.14*	-0.52*	0.25	-0.01	-0.74*
PBW 243	0.16	-1.09*	-0.16*	-0.17	-0.19	-0.29
DH 3171	-1.58*	-0.86*	-1.41*	0.03	0.17	0.35*
PBW 502	-2.78	-0.99*	-0.13*	0.04	0.33*	-0.46

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Parents	GS	GWS	TW	GYP	BYP	FLA
LAWL-1	1.84*	-0.24*	-0.98*	0.12	1.75*	0.49
HUW-206	0.14	-0.15	-0.09	0.48*	-0.11*	-1.44
Allahabad local	1.19*	-0.20	-0.04	-0.09	0.46	-1.95*
Shriram-303	-0.58	0.03	0.00	0.10	0.16	;-1.06*
RAJ 4120	-0.57	0.19*	0.65*	-0.17*	0.81*	0.30
PUSA 2733	-0.13	0.10	0.15	0.09	-0.11	0.74
RAJ 4037	0.12	0.10	0.29*	0.19*	-0.48	0.66
PBW 243	-0.51*	0.06	0.06	0.06	-0.75	1.19*
DH 3171	-0.27	0.09	-0.07	0.31	1.25*	-0.22
PBW 502	-1.21	-0.04	0.54*	0.16	0.52*	1.28*

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Parents	SM	SD	SG	SV	FT	GC	HI
LAWL-1	-0.03*	0.32*	0.33*	0.18	19.64**	21.69**	2.83*
HUW-206	0.08	-0.02	0.72	0.49*	3.90	-5.82**	-1.38*
Allahabad local	-0.08*	0.08	0.33	-0.58*	-12.18**	-4.91	-1.17
Shriram-303	0.01	-0.03	0.50	-0.10	3.24	-5.56	-0.15
RAJ 4120	0.19*	-0.06	-4.63*	0.25	2.67	-5.03	-1.98*
PUSA 2733	0.05	0.07	0.86	-0.23	-13.74**	-5.91**	0.06
RAJ 4037	0.16*	-0.23*	0.77	0.38	1.54	-4.81	1.11
PBW 243	-0.03	0.07	-0.38	-0.14	-2.92	-5.50	1.19*
DH 3171	-0.16	-0.07	0.61	0.15	-5.13**	21.6**	-0.81
PBW 502	-0.11	-0.06	0.91*	-0.40	2.97	-5.72**	0.32

Table: 3. Estimate of specific combining ability (SCA) effects

Crosses	PH	DFF	DM	ETP	SL
LAWL-1 X HUW-206	-0.71**	-1.44**	-1.35**	0.30**	0.68**
LAWL-1 X Allahabad local	-1.39	2.22**	0.59	0.17	-0.04
LAWL-1 X Shriram-303	7.96	0.15	-1.49**	0.10	1.10**
LAWL-1 X RAJ 4120	-2.22	0.40	-0.35	0.42	-0.24
LAWL-1 X PUSA 2733	-8.64	0.61	0.65	1.11**	0.55
LAWL-1 X RAJ 4037	-6.84	5.31**	3.09**	0.83	-0.49
LAWL-1 X PBW 243	-3.41	1.03**	-1.43**	-0.07	0.45
LAWL-1 X DH 3171	10.58	-4.40	-0.52	-0.29	0.35
LAWL-1 X PBW 502	10.51	1.50	-1.13**	-0.29	-1.08
HUW-206 X Allahabad local	1.07	1.55	-1.74**	0.97	-0.40
HUW-206 X Shriram-303	5.98	-1.32	0.84	-0.06	-1.26
HUW-206 X RAJ 4120	-4.19	-2.94	-0.02	0.46	0.63
HUW-206 X PUSA 2733	0.36	0.87	-1.69	0.66	1.52**
HUW-206 X RAJ 4037	6.15**	5.10**	-0.91	0.03	1.57*
HUW-206 X PBW 243	4.98	-2.78	-2.10	-0.40	0.76
HUW-206 X DH 3171	-0.43	-2.34	-2.19	1.25**	0.16
HUW-206 X PBW 502	-3.14	0.46	-1.47	0.25	0.22
Allahabad local X Shriram-303	-0.09	0.72	0.12	-0.33	0.35
Allahabad local X RAJ 4120	-3.43	0.90	-2.07**	-0.68	-0.30
Allahabad local X PUSA 2733	5.15**	-6.39**	-4.07**	1.02	0.79
Allahabad local X RAJ 4037	0.08	-0.72	-0.63	-0.11	-0.15
Allahabad local X PBW 243	1.81	1.90	-0.83	1.36**	-0.34
Allahabad local X DH 3171	-2.76**	1.00	-0.58	0.28	0.00
Allahabad local X PBW 502	3.42**	0.63	2.15	0.11	1.16**
Shriram-303 X RAJ 4120	5.72	-0.24	-1.49	0.65	1.48
Shriram-303 X PUSA 2733	-5.53**	2.03	-2.15**	-0.58	0.94
Shriram-303 X RAJ 4037	-5.77	-2.12**	-1.71**	-0.37	0.29
Shriram-303 X PBW 243	7.82	-1.18	-1.24	-0.34	0.67

Shriram-303 X DH 3171	-5.42	-0.41	-1.33	-0.39	0.81
Shriram-303 X PBW 502	-0.56	3.82**	-0.94	0.44**	-0.69
RAJ 4120 X PUSA 2733	0.99	-0.08	-1.69	0.67**	-0.11
RAJ 4120 X RAJ 4037	2.25	-1.24	-0.91	0.38	-1.29
RAJ 4120 X PBW 243	4.65	1.71	2.23	-0.18	-0.77
RAJ 4120 X DH 3171	-2.26	3.47	-0.52	0.03	0.06
RAJ 4120 X PBW 502	1.93	0.61	-3.13	-0.83**	1.36**
PUSA 2733 X RAJ 4037	6.83	0.80	-0.58	0.82	0.71
PUSA 2733 X PBW 243	0.56	1.75	0.90	-0.02	1.29
PUSA 2733 X DH 3171	-2.68	2.85	-0.85	0.30	-0.38
PUSA 2733 X PBW 502	2.85	-0.68	-3.13**	-0.54	0.59
RAJ 4037 X PBW 243	-6.18	-0.25	-0.66	-0.97	0.68
RAJ 4037 X DH 3171	-3.76	-1.15	-0.41	0.34	-0.36
RAJ 4037 X PBW 502	1.44	-2.01	1.68**	0.81	-0.09
PBW 243 X DH 3171	-7.69**	-1.53**	-0.60	1.11*	-0.18
PBW 243 X PBW 502	-7.49**	1.27	1.45	0.18	0.32
DH 3171 X PBW 52	4.26	0.71	0.37	-0.04	1.29**

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Crosses	**SS**	**GS**	**GWS**	**TW**	**GYP**
LAWL-1 X HUW-206	-1.49**	2.27**	0.20**	0.61**	0.267**
LAWL-1 X Allahabad local	1.48**	1.06**	0.21**	-0.44	0.68
LAWL-1 X Shriram-303	2.15	0.27	-0.16	1.18	0.14
LAWL-1 X RAJ 4120	-0.28	-1.60**	-0.11	0.86**	1.09
LAWL-1 X PUSA 2733	0.73	-0.67	-0.03	-0.30	-0.85
LAWL-1 X RAJ 4037	-0.61	0.53	-0.33	0.56	1.72**
LAWL-1 X PBW 243	0.07	2.54	0.38	1.44**	0.08
LAWL-1 X DH 3171	3.65**	-0.27	0.11**	-1.08	1.93
LAWL-1 X PBW 502	1.35	-0.76	-0.45	-2.52**	0.08

HUW-206 X Allahabad local	-0.16	3.75**	0.27	2.00	1.37
HUW-206 X Shriram-303	3.21	-4.07	0.23	0.29	-0.16
HUW-206 X RAJ 4120	1.54	-2.71	-0.46	1.30	-0.55
HUW-206 X PUSA 2733	1.62	-0.28	-0.48	-0.20	0.85
HUW-206 X RAJ 4037	3.28**	-0.01	-0.28	0.33	1.75
HUW-206 X PBW 243	-0.11	1.70	0.10	-0.11	-0.06
HUW-206 X DH 3171	-0.69	1.86	-0.23	0.03	-0.04
HUW-206 X PBW 502	1.57**	-0.93	0.00	0.92	1.44**
Allahabad local X Shriram-303	0.29	-0.51	-0.33	1.58	0.12
Allahabad local X RAJ 4120	0.42	-0.79	0.08	-1.07	-1.27
Allahabad local X PUSA 2733	2.33**	0.98	-0.16	3.43	0.46
Allahabad local X RAJ 4037	1.22**	-2.85**	-0.03	0.62	0.70
Allahabad local X PBW 243	0.41	0.75	-0.28**	-0.49	0.56
Allahabad local X DH 3171	0.19	-0.22	0.08	2.31**	0.57
Allahabad local X PBW 502	1.25	-1.48	-0.12	0.54	2.05**
Shriram-303 X RAJ 4120	-1.11	-0.31	-0.29	-0.46	1.59**
Shriram-303 X PUSA 2733	0.90	0.15	0.23	1.04	-0.08
Shriram-303 X RAJ 4037	1.63	-3.00**	-0.21	-1.10	0.83
Shriram-303 X PBW 243	0.61	1.62**	0.04	2.79	2.68**
Shriram-303 X DH 3171	1.79	1.06	0.38	0.27	0.70
Shriram-303 X PBW 502	1.09	-1.67	0.57	2.82**	-0.15
RAJ 4120 X PUSA 2733	0.54	-2.42**	-0.13	1.06	1.20
RAJ 4120 X RAJ 4037	0.76	-2.35**	0.11	1.25**	-0.89
RAJ 4120 X PBW 243	0.84	-4.04**	0.05	2.14	-0.70
RAJ 4120 X DH 3171	-0.31	-1.62	0.46	-1.39	0.98
RAJ 4120 X PBW 502	1.82	1.16	0.45	-0.16	2.46**
PUSA 2733 X RAJ 4037	0.01	0.48	0.55**	-0.25	1.17
PUSA 2733 X PBW 243	1.15**	0.35	0.51	-0.36	0.69
PUSA 2733 X DH 3171	0.07	0.28	0.47	2.45	0.71
PUSA 2733 X PBW 502	1.60	0.39	-0.10	-0.66	0.19
RAJ 4037 X PBW 243	-0.58	-0.55	0.44	-1.83	-0.73**

RAJ 4037 X DH 3171	0.97	-0.82	0.04	0.64	0.65**
RAJ 4037 X PBW 502	-1.24	-1.00**	-0.13	2.53**	0.10
PBW 243 X DH 3171	0.15	0.32	0.78**	2.20	1.81
PBW 243 X PBW 502	-0.19	-0.74	0.05	2.09	2.29
DH 3171 X PBW 52	2.98**	-0.01	-0.05	-0.77	0.30

Continue…

Crosses	**BYP**	**FLA**	**SM**	**SD**	**SG**
LAWL-1 X HUW-206	0.376**	3.24**	0.94**	0.05**	-0.57**
LAWL-1 X Allahabad local	1.37	-0.75	0.11	-0.03	0.48**
LAWL-1 X Shriram-303	2.44**	2.82**	-0.66	0.08	0.65
LAWL-1 X RAJ 4120	3.69**	-0.80	-0.41	-0.35**	4.79
LAWL-1 X PUSA 2733	4.01**	-3.25	-0.36	0.29	-1.05
LAWL-1 X RAJ 4037	1.65	-1.43	0.20	0.15	-0.30
LAWL-1 X PBW 243	-0.40	-5.14	0.06	0.48**	-0.80
LAWL-1 X DH 3171	-2.55	0.19	-0.47	-0.08	-0.46
LAWL-1 X PBW 502	-0.02	3.04**	-0.53	0.05	-0.43
HUW-206 X Allahabad local	-2.77	2.79**	-0.67	-0.52	0.07
HUW-206 X Shriram-303	-2.66	2.10	0.56**	0.34	0.23
HUW-206 X RAJ 4120	-1.18	0.57	-0.19	0.27	5.70**
HUW-206 X PUSA 2733	-1.38	0.23	0.20	-0.17	-0.80
HUW-206 X RAJ 4037	3.05**	-1.79	-0.58	-0.25	-1.38
HUW-206 X PBW 243	2.80	-3.49**	0.28	-0.15	-0.88
HUW-206 X DH 3171	3.88**	1.17	0.09	0.35	-1.55
HUW-206 X PBW 502	-0.42	-5.98	-0.64	-0.03	-1.52
Allahabad local X Shriram-303	-0.61	-2.19	0.39	0.67	-1.38
Allahabad local X RAJ 4120	2.80	-4.92	0.64	-0.53**	4.09
Allahabad local X PUSA 2733	0.36	-6.32**	1.02**	-0.22	-0.07
Allahabad local X RAJ 4037	-2.24	-4.11	0.25	0.17	0.01

Allahabad local X PBW 243	2.70**	-3.15	-0.89	0.02	-0.49
Allahabad local X DH 3171	-2.97**	0.88	-0.09	0.09	-0.49
Allahabad local X PBW 502	5.39**	-4.80	0.53	0.43**	-1.13
Shriram-303 X RAJ 4120	3.51	2.66	0.20	0.31	3.92**
Shriram-303 X PUSA 2733	-1.60	-2.09	-0.74	-0.43	-0.24
Shriram-303 X RAJ 4037	0.20	-5.24	-0.19	0.06	-0.16
Shriram-303 X PBW 243	1.18	-10.07**	-0.33	-0.56	-0.99
Shriram-303 X DH 3171	-0.07	-10.58**	0.15	-0.01	-0.66
Shriram-303 X PBW 502	-1.94	-0.39	0.43	0.33	-1.63
RAJ 4120 X PUSA 2733	0.52	1.85	-0.50	0.08	4.23
RAJ 4120 X RAJ 4037	-3.72	-0.40	0.39**	0.25	3.65
RAJ 4120 X PBW 243	-2.30	5.46	0.25	0.61**	6.14**
RAJ 4120 X DH 3171	-0.99	-7.11	-0.61	-0.03	5.81**
RAJ 4120 X PBW 502	0.41	-11.49	-0.33	-0.10	4.84**
PUSA 2733 X RAJ 4037	-2.65	-1.71	-0.55	0.23	-2.18**
PUSA 2733 X PBW 243	2.29	-2.25	0.31	-0.02	-2.02
PUSA 2733 X DH 3171	2.28	2.44	0.78**	0.12	-1.02
PUSA 2733 X PBW 502	-0.66	0.03	0.39	0.54**	0.34
RAJ 4037 X PBW 243	-1.34	0.10	-0.14	0.22	-0.93
RAJ 4037 X DH 3171	2.07**	6.02**	-0.33	-0.21	0.73
RAJ 4037 X PBW 502	1.54	4.48**	0.61	-0.28	1.43
PBW 243 X DH 3171	-0.18	1.39	0.53	-0.39	-0.10
PBW 243 X PBW 502	-5.01**	1.88	-0.19	-0.25	-0.41
DH 3171 X PBW 52	-4.03	1.97	0.61**	0.09	-0.74

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Crosses	**SV**	**FT**	**GC**	**HI**
LAWL-1 X HUW-206	-0.57	2.09**	-22.08**	-0.91**
LAWL-1 X Allahabad local	1.26**	18.85**	-23.01**	-0.64

LAWL-1 X Shriram-303	0.83**	7.09**	-21.35**	-2.97
LAWL-1 X RAJ 4120	0.07	0.99	-22.32**	-2.94
LAWL-1 X PUSA 2733	0.80	19.74**	-21.38	-9.61**
LAWL-1 X RAJ 4037	2.37**	-6.88	-22.99	3.22
LAWL-1 X PBW 243	0.01	-1.41	-21.29	1.92
LAWL-1 X DH 3171	-0.21	-3.20	17.04**	10.65**
LAWL-1 X PBW 502	-1.01	-1.31	-20.84**	0.03
HUW-206 X Allahabad local	0.30	10.25**	5.46	8.96
HUW-206 X Shriram-303	2.26**	-4.84	5.45	3.76**
HUW-206 X RAJ 4120	0.17	-6.94	4.49	1.77
HUW-206 X PUSA 2733	-0.07	15.48	5.15	4.95
HUW-206 X RAJ 4037	0.63	-7.48	3.62	0.42
HUW-206 X PBW 243	0.46	0.46	5.35	-4.56
HUW-206 X DH 3171	-0.59	-3.46	-21.82**	-5.39**
HUW-206 X PBW 502	0.38	-5.24	6.02	5.45**
Allahabad local X Shriram-303	-1.76	-12.07**	5.70	0.74
Allahabad local X RAJ 4120	1.54	-10.51	4.26	-6.15
Allahabad local X PUSA 2733	-0.80	4.91	5.21	0.04
Allahabad local X RAJ 4037	-1.44	-8.71	5.67	5.84
Allahabad local X PBW 243	-2.15	-4.91	4.98	-2.20
Allahabad local X DH 3171	0.17	-10.37**	-22.23	6.16
Allahabad local X PBW 502	1.78	-5.48	4.63	-2.01
Shriram-303 X RAJ 4120	-3.89	-2.94	4.57	-0.86
Shriram-303 X PUSA 2733	0.87	16.48	4.78	2.62
Shriram-303 X RAJ 4037	1.97	0.99	3.61	2.42
Shriram-303 X PBW 243	0.23	4.33	4.91	6.30
Shriram-303 X DH 3171	-1.44	10.54	-22.17**	2.05
Shriram-303 X PBW 502	0.24	-9.24	5.41	3.83
RAJ 4120 X PUSA 2733	0.78	3.38	6.52	2.35
RAJ 4120 X RAJ 4037	-2.42	-23.24**	5.30	2.32
RAJ 4120 X PBW 243	-0.30	-0.44	6.05	0.93

RAJ 4120 X DH 3171	1.58	11.44	-21.14	4.14
RAJ 4120 X PBW 502	0.32	4.33	2.76	6.51**
PUSA 2733 X RAJ 4037	-3.23	-16.49**	3.48	9.26**
PUSA 2733 X PBW 243	2.10**	-9.69	4.16	-0.67
PUSA 2733 X DH 3171	-1.78	-9.15	-22.86	-1.02
PUSA 2733 X PBW 502	-0.86	-20.25**	3.54	0.90
RAJ 4037 X PBW 243	0.57	10.69	5.56**	-1.05
RAJ 4037 X DH 3171	-0.30	16.89**	21.90**	-2.34
RAJ 4037 X PBW 502	-1.09	18.45**	6.42	-2.73
PBW 243 X DH 3171	1.18	14.76**	-22.31	5.48
PBW 243 X PBW 502	0.63	13.25**	5.34	17.39**
DH 3171 X PBW 52	0.36	9.46	-21.53	6.40**