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Research Article

Inheritance and combining ability of grain yield in half diallel barley population

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Abstract

Studies on genetic control of grain yield are of great importance for devising effective breeding programmes for yield gain in barley. Hence, inheritance of grain yield, heterosis and combining ability were investigated in barley population obtained from half-diallel crossing among 7 parental lines. The analysis of variance revealed that mean squares due to genotypes were highly significant for grain yield indicating wide diversity among the parental materials used in the study. Mean squares of general combining ability (GCA) and specific combining ability (SCA), the ratio of GCA to SCA mean squares and portion of additive and dominance variances showed, importance of both additive and non-additive gene effects for grain yield. The non significant ratio of GCA to SCA mean square highlighted that non-additive gene effects were more important than additive effects. Distribution of dominant and recessive alleles in parents were asymmetrical and parents possess majority of recessive alleles. Since average degree of dominance has values greater than 1, which indicated over-dominance type of gene action in the inheritance of the grain yield. The parent BHS400 was considered suitable according to its yield capacities and general combining ability effects. Only 2 crosses viz., BHS400 X RD2660 and BHS400 X RD2552 had significant higher grain yield than that of the check variety (BHS400), high significant SCA values and high significant useful heterosis values. Considering average narrow-sense heritability and over-dominant effects in genetic control of grain yield it is better to postpone selection for this trait until advanced breeding generations.

Keywords: Barley, general combining ability, grain yield, half diallel analysis, heterosis and specific combining ability

1. Introduction

Providing raw material for the brewery industry, animal fodder, food for people particularly of higher altitudes of India, barley (*Hordeum vulgare* L.) is one of the major cereal crops. In India, barley productivity is below the world average level due to its cultivation under marginal lands, minimum input management conditions and slow varietal replacement rate. Barley production can be increased either by bringing more area under cultivation or by developing new high yielding cultivars. Since area is a limiting factor, new barley varieties with high genetic potential for grain yield needs to be developed, for which several breeding procedures have been established (Ramage, 2011; Friedt *et al.*, 2011). Varietal improvement through plant breeding depends upon the genetic information available from parents and their cross combinations governing qualitative and quantitative traits. Therefore, for development of an effective breeding programme in barley, one need to elucidate the genetic nature and magnitude of quantitatively inherited traits and estimated pre-potency of parents in hybrid combinations. To derive such genetic information of parents and progenies, as well as for their general and specific combining ability, it is necessary to frame a genetic model in relation to the experimental material.

Various models have been created in order to estimate general and specific combining ability of parents and crosses. Of these, diallel analysis is a suitable method for estimating genetic parameters and providing early information on the genetic behaviour of the traits under consideration. This method has been used in different crops, including barley (Kakani *et al.*, 2007; Madic *et al.,* 2005; Madhukar *et al.*, 2018). Griffing (1956 a, b) expressed analysis of diallel crosses in four various methods - complete diallel with parents and reciprocals, complete diallel excluding parents, half diallel with parents but without reciprocals and half diallel without parents or reciprocal crosses. Among various diallel forms, the half diallel methods (without reciprocal crosses) have certain advantages over others, giving maximum information about genetic architecture of a trait, parents and allelic frequency, and has the most use because of easiness in conduct. In this, the combining ability describes the breeding values of parental lines to produce specific cross combinations. Crossing a line to several others provides the mean performance of the line in all its crosses. This mean performance, when expressed as a deviation from the mean of all crosses, is called the general combining ability (GCA) of the line. Any particular cross, then, has an expected value which is the sum of the general combining abilities of its two parental lines. The cross may, however, deviate from this expected value to a greater or lesser extent. This deviation is called the specific combining ability (SCA) of the two lines in combination. The general combining ability effects helps in selection of superior parents and specific combining ability effects helps in selection of superior hybrids. Heterosis is defined as the percentage of F_1 cross over the parental mean, and generally high heterosis values are desirable for improvement in grain yield. Researchers have reported different heterosis values for grain yield in barley. Bernhard *et al.* (2017) reported the average best-parent heterosis of 7.7%; Amer *et al.* (2012) estimated mid parental heterosis ranging from -30.4 to 61.2% and better parental heterosis from -36.4 to 34.9% whereas, Potla *et al.* (2013) reported standard heterosis values from –7.38% to 32.80% in barley for grain yield. Since varietal development is a continuous process in barley, therefore, the present study have generated information on the nature of gene action, selection of suitable parents and crosses, and devising suitable breeding strategy for gain yield improvement in barley.

2. Materials and methods

Seven barley varieties (Table1) representing a range of grain yield were crossed in a 7 x 7 half-diallel mating scheme to obtain the F_1 seeds in 2015-16 growing season.

Methodology: The experiment was conducted at ICAR-Indian Agricultural Research Institute, Regional Station, Shimla, Himachal Pradesh (India) during the year 2015-16 (for making crosses) and 2016-17 (for combining ability studies). The parents, their 21 F_1 progenies were sown during 2016-17 in randomized complete block design with three replications. Each entry was grown in 2 rows, 3 m long and spaced 22cm apart.

Statistical analysis: Data obtained from the 21 F_1 progeny and 7 parents were analyzed for genetic parameters by diallel analysis (Jinks and Hayman, 1953). The combining ability analysis was done as per Griffing's Method 2 Model 1 (Griffing, 1956 b). The significance of GCA and SCA effects was determined at the 1 and 5 per cent level using t-test. Midparent (MP) heterosis was calculated by using the mean of the parents [(F_1-MP)/MP] and useful heterosis values were calculated using the mean of BHS400- the check variety [(F_1- MCV)/MCV]. The narrow sense heritability was calculated according to the method of Mather and Jinks (1971).

Table 1. List of barley varieties used for half diallel study with their parentage

SN	Variety	Parentage
1	BHS 380	VIOLETA/MJA/7/ABN-B/6/BA/ GAL// FZA-B/5/DG/DC-B/PT-BAR/3/RA-B/ BA*3/4/TRYIGAL
2	BHS400	34th IBON-9009
3	BHS352	HBL240/BHS504//VLB129
4	VLB110	GOB91DH/ALELI/3/ARUPO/K8755// MORA
5	VLB115	33rd IBON-11
6	RD2552	RD-2035/DL 472
7	RD2660	RD 2052 / RD 2566

3. Result and discussion

The analysis of variance (Table 2) revealed that mean squares due to genotypes were highly significant for grain yield trait, indicating wide diversity among the parental material used in the present study. Mean squares of GCA and SCA were highly significant and explain importance of both additive and non-additive gene effects on genetic control of grain yield. But non- significant ratio of GCA to SCA mean square showed that non-additive gene effects were more important than additive effects in genetic control of grain yield. Baghizadeh *et al.* (2003), Sharma *et al.* (2003), Verma *et al.* (2007), Islam and Darrah (2005) and Madhukar *et al.* (2018) also emphasized higher portion of non-additive gene effects in genetic control of grain yield in barley and believed that selection for improving this trait must be delayed until later breeding generations. Conversely, Mansour (2012) and Mansour (2017) indicated a higher contribution of the additive component, whereas

Prakash *et al.* (2005), Raikwar (2014) and Kakani and Sharma (2010) highlighted the importance of both additive and non-additive genetic variance components in determining grain yield and yield components in barley. The value of ratio of GCA/SCA in our study was similar to the findings of Madic *et al.* (2014).

Table 2. Mean squares and combining ability of grain yield in 7 X 7 half diallel barley crosses

Source of variation	d.f	Mean squares
Replication	2	26.67**
Genotype	27	58.17**
Error (Preliminary)	54	3.67
G.C.A.	6	47.59*
S.C.A	21	11.33*
Error (combining ability)	54	1.22
GCA/SCA		4.22

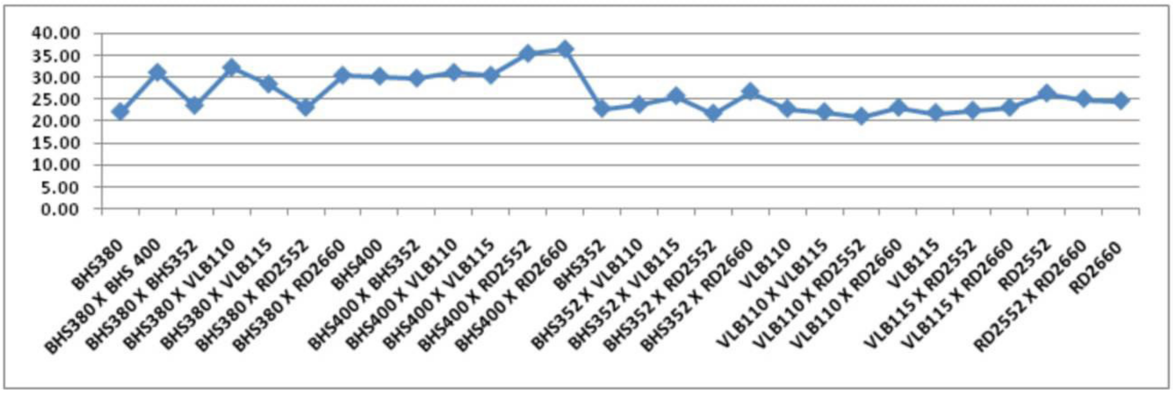
* and ** indicate significant differences at 0.05 and 0.01 levels, respectively

Mean yield of parents and F_1's of barley is given in Fig1. Estimates of combining ability revealed that the parent 'BHS400' had the highest significant and positive GCA effects (4.87) (Table 3) and was the best general combiner for increasing grain yield in barley. Considering high means of this cultivar and its GCA effect for grain yield, selection from progenies of this cultivar crosses will not only improves grain yield, but also increase genetic efficiency of selection. The finding lends support from the studies of Joshi and Singh (2004), Kakani *et al.* (2007) and Rathore and Chauhan (2017). Genotype VLB115 was the poorest general combiner with maximum negative significant GCA effects (-1.64). Negative GCA effects were also observed in BHS352, VLB110 and RD2552. The Wr+Vr values indicates that the parent BHS400 carries the highest number of dominant alleles while RD2552 and RD2660 had low frequency of dominant alleles (Table 3).

Table 3. Mean of parents and general combining ability (GCA) effects for grain yield in barley

Parents	Yield (Q/ha)	GCA effect	Wr + Vr values
BHS380	22.01	0.25	-0.05
BHS400	30.13	4.87**	-1.24
BHS352	22.75	-1.53**	-0.89
VLB110	22.73	-1.31**	0.23
VLB115	21.83	-1.64**	-0.49
RD2552	26.28	-1.02**	1.54
RD2660	24.53	0.37	1.02
S.E.(gj)		0.34	

Fig. 1 Mean grain yield of parents and F_1 in half diallel cross of barley



Most of the crosses of BHS400 had positive and significant SCA effects (Table 4), which may be another reason for efficiency of selection among progenies of these crosses. Also, in this study, crosses (BHS380 X VLB110; BHS400 X RD2552 and BHS400 X RD2660) which displayed significant high specific combining ability effects for the grain yield were obtained from parents with various types of general combining ability effects (average x poor, good x poor, good x average, respectively). Estimates of SCA effects were positive and highest in cross BHS380 x VLB110 (6.94) followed by BHS400 X RD2552 (5.22), BHS400 X RD2660 (4.83), HS380 X VLB110 and BHS380 X RD2660 (3.46) with significant values. Tendency of positive significant values of SCA effects was also observed in crosses BHS352 X RD2660 (1.57) and BHS400 X VLB110 (1.18). Greater SCA effects obtained in these crosses, which involved one parent with average or good GCA, indicated the involvement of additive x dominance gene interaction in the expression of this trait. According to Borojevic (1986), parents with high values of SCA are good combination of filial generation and uses dominant gene action. The significant highest negative value for estimates of SCA effects was shown by VLB110 X RD2552 (-2.93) followed by BHS380 X RD2552 (-2.49) and VLB110 X RD2660 (-2.32). Significant negative SCA effects were also observed in crosses BHS352 X RD2552 (-2.04), VLB115

X RD2660 (-1.99), BHS380 X BHS352 (-1.51), VLB110 X VLB115 (-1.31) and VLB115 X RD2552 (- 1.27). The most promising crosses for improving grain yield were BHS380 X VLB110, BHS400 X RD2552 and BHS400 X RD2660, because they gave the highest positive significant SCA for grain yield. These crosses also exhibited higher yield and one of the parents in each cross was a good general combiner indicating that such combinations are expected to produce desirable transgressive segregants. Results obtained from this study agree with results obtained by Sharma *et al.* (2002), Madic *et al.* (2014) and Zhang et al. (2015). The heterosis values estimated for grain yield in a 7 x 7 half diallel of barley crosses are given in Table 4. The mid-parent heterosis ranged from -14.31% to 43.62%. The useful heterosis values were calculated according to the performance of the check variety, BHS400 (30.13 Q ha-1) and value of useful heterosis varied from -7.69 % (VLB110 X RD2552) to 59.71% (BHS400 X RD2660). Only 2 crosses viz., BHS400 X RD2660 and BHS400 X RD2552 had grain yields higher than that of the check variety and having higher and significant useful heterosis values of 59.71 and 55.31, respectively (These crosses also had highest significant positive SCA). These crosses exhibited higher yield and one of the parents in each cross was a good general combiner indicating that such combinations are expected to produce desirable transgressive segregants. Bernhard *et al.* (2017) reported the average best-parent heterosis of 7.7% for grain yield, whereas Potla *et al.* (2013) reported standard heterosis values from –7.38% to 32.80% for grain yield in barley. The differences between the estimated heterosis values in this study and those reported previously might be due to the use of different genetic materials and different environmental conditions.

Table 4. Mean yield, specific combining ability (SCA) effects and heterosis value for grain yield in barley

Crosses	Yield (Q/ha)	SCA effects	Mid-parent heterosis (%)	Economic heterosis (%)	GCA Status of the parents
BHS380 X BHS400	31	-0.38	18.90**	36.26**	A x G
BHS380 X BHS352	23.47	-1.51**	4.85	3.15	A x P
BHS380 X VLB110	32.13	6.94**	43.62**	41.25**	A x P
BHS380 X VLB115	28.33	3.46**	29.24**	24.54**	A x P
BHS380 X RD2552	23	-2.49**	-4.76	1.1	A x P
BHS380 X RD2660	30.33	3.46**	30.34**	33.33**	A x A
BHS400 X BHS352	29.67	0.06	12.20*	30.40**	G x A
BHS400 X VLB110	31	1.18*	17.28**	36.26**	G x P
BHS400 X VLB115	30.33	0.84	16.74**	33.33**	G x P
BHS400 X RD2552	35.33*	5.22**	25.26**	55.31**	G x P
BHS400 X RD2660	36.33*	4.83**	32.93**	59.71**	G x A
BHS352 X VLB110	23.67	0.25	4.07	4.03	P x P
BHS352 X VLB115	25.67	2.57**	15.14*	12.82	P x P
BHS352 X RD2552	21.67	-2.04**	-11.62*	-4.76	P x P
BHS352 X RD2660	26.67	1.57**	12.80*	17.22*	P x A
VLB110 X VLB115	22	-1.31**	-1.27	-3.3	P x P
VLB110 X RD2552	21	-2.93**	-14.31*	-7.69	P x P
VLB110 X RD2660	23	-2.32**	-2.68	1.1	P x A
VLB115 X RD2552	22.33	-1.27**	-7.17	-1.83	P x P
VLB115 X RD2660	23	-1.99**	-0.79	1.1	P x A
RD2552 X RD2660	25	-0.61	-1.61	9.89	P x A

* and ** indicate significant differences at 0.05 and 0.01 levels, respectively.
P, A, G: Poor, average and good GCA effects

Inheritance of grain yield, analysed by components of genetic variance is shown in Table 5. The parameter E, an estimate of the genotypic environmental variation and parameter D (which include a portion of the additive x additive epistatic variances as well as additive genetic variance) was non-significant for grain yield. The components of variance resulting from dominant gene action in F_1 generation (H1 and H2) were greater than the variance component D, follows that the expression of grain yield is conditioned by dominant gene action. Mean degree of dominance showed that yield was affected by complete dominance gene effects. The average value of the F parameter is negative but it is not significant and it may be accepted that the dominant and recessive alleles in the populations were about equal. However, the unequal values of H1 and H2 indicate that the distribution of dominant and recessive alleles in parents is asymmetrical. Even the ratio H2/4H1 expresses uneven distribution of the dominant and recessive alleles in the parental forms. The parents possesses majority of recessive alleles and minority of dominant alleles (since 0.63<1.0), this is further supported by negative F value (interaction additive x dominant effect). Similar results, which indicated a larger value of the dominant component in the genetic variance of the grain yield have been pointed out by Bargougui (2017), Yadav (2016), Sharma et al. (2002), Raikwar (2014) and Madhukar *et al.* (2018). Since the mean dominance effect of the heterozygote locus (h2) was significant, high heterotic effect values would be expected for grain yield among crosses. The average degree of dominance ($\sqrt{}$(H1/D)= 2.45) has greater values than 1, which indicated over-dominance type of gene action in the inheritance of the grain yield. The heritability value depicts that grain yield in barley is moderately heritable. Considering average narrow-sense heritability and high importance of dominant effects in genetic control of grain yield it is better to postpone selection for improving this trait until advanced breeding generations. For this goal, we emphasize use of 'BHS400' cultivar and its progenies

Table 5. Genetic parameters and ratios estimated for grain yield from 7 X 7 half diallel barley population

Genetic parameters and ratios	Grain Yield
F	-8.40 ± 9.24
D	7.53±3.85
E	1.49±1.36
h2	18.76±5.48**
H1	45.07 ± 9.28**
H2	34.16±8.17**
(H1/D)1/2	2.45
K	0.55
Heritability (narrow sense)	0.57
r	0.004
Proportion of dominant and recessive alleles in the parents	0.63

* and ** indicate significant differences at 0.05 and 0.01 levels, respectively

Conclusion

This study was undertaken by means of half diallel analysis of grain yield of F_1 barley hybrids to establish some genetic parameters and indexes of inheritance necessary for specifying the breeding strategy for this character. The study highlighted the rewarding parents and crosses of barley that can be exploited by barley breeders to launch effective breeding strategies. According to the analysis of variance for combining ability it was concluded that both additive and non-additive gene effects were responsible for the inheritance of the grain yield. The variety, BHS400, had significant positive GCA effects and therefore would be an important genotype to develop progeny having higher yield. On the other hand, VLB115 contributed least to grain yield. It is noteworthy that only 2 crosses viz., BHS400 X RD2660 and BHS400 X RD2552 had grain yields significantly higher than that of the check variety and having higher and significant useful heterotic values. Therefore, to synthesize a dynamic population with most of the favourable genes accumulated, it will be pertinent to make use of BHS400, which is a good general combiners for grain yield and the crosses highlighted can be exploited vigorously in future barley breeding programmes to produce desirable transgressive segregants to achieve high yields. Since non-additive type of gene action was found, thereby suggesting that selection of superior plants should be deferred to later generation and the population improvement appears to be a promising approach.

References

1. Amer KH, A Eid, A Elakhdar and E El-Shawy. 2012. Combining ability and heterosis in five barley genotypes for some economic traits. *Egyptian Journal of Agricultural Research* **90**: 105-116.
2. Baghizadeh A, A Taleai, R Naghavi and HZ Khanaghah. 2003. Evaluation of some quantitative characters in barley using mean generation analysis. *Iranian Journal of Agricultural Sciences* **35**: 851–857.
3. Bargougui MA.2017. Genetic analysis of barley (*Hordeum vulgare* L.) grain yield components. *Journal of New Sciences* **31 (8)**:1794-1799.
4. Bernhard T, W Friedt, KP Voss-Fels, M Frisch, RJ Snowdon and B Wittkop. 2017. Heterosis for biomass and grain yield facilitates breeding of productive dual-purpose winter barley hybrids. *Crop Breeding and Genetics* **57 (5)**: 2405-2418.
5. Borojevic K. 1986. Genes and populations. University of Novi Sad, Faculty of Agriculture.
6. Friedt W, RD Horsley, BL Harvey, DM Poulsen, R Lance, S Ceccarelli and F Capettini. 2011. Barley breeding history, progress, objectives, and technology In Ullrich S. E., editor. (Ed.), Barley: Production, Improvement, and Uses (pp. 160–220). Oxford, UK: Blackwell Publishing Ltd.
7. Griffing B. 1956 a. A generalised treatment of the use of diallel crosses in quantitative inheritance. *Heredity* **10**: 31-50.
8. Griffing B. 1956 b. Concept of general and specific combining ability in relation to diallel crossing systems. *Australian Journal of Biological Science* **9**: 463-493.

9. Islam AA and M Darrah. 2005. Estimation of gene effects for seed yield and component traits in hulless barley. *Turkish Journal of Field Crops* **8**: 85– 92.
10. Jinks J and BI Hayman. 1953. The analysis of diallel crosses. *Maize Genetics New Letter* **27**: 48-54.
11. Joshi RP and AK Singh. 2004. Combining ability for seedling traits and grain yield in barley. *JNKVV Research Journal* **38**(**2**): 9- 12.
12. Kakani RK and Y Sharma. 2010. Genetic component analysis for yield and yield contributing traits under diverse environments in barley. *SABRAO Journal of Breeding and Genetics* **42**(**1**): 9-20.
13. Kakani RK, Y Sharma and SN Sharma. 2007. Combining ability of barley genotypes in diallel crosses. *SABARO Journal of Breeding and Genetics* **39**(**2**): 117-126.
14. Madhukar K, LC Prasad, JP Lal, R Prasad and K Chandra. 2018. Generation mean analysis for yield and drought related traits in barley (*Hordeum vulgare* L.) *International Journal of Pure and Applied Biological Science* **6** (**1**): 1399-1408.
15. Madic M, A Paunovic, D Durovi., BM Kraljvic and D Knezivic.2005. The analysis of gene effect in the inheritance of kernel number per spike in barley hybrid. *Genetika* **37**: 261-269.
16. Madic MR, DS Djurovic, DS Knezevic, AS Paunovic and ST Tanaskovic. 2014. Combining abilities for spike traits in a diallel cross of barley. *Journal of Central European Agriculture* **15**(**1**): 108-116.
17. Mansour MA. 2012. Genetical studies on some barley genotypes and its tolerance to drought. Ph.D. Thesis. Faculty of Agriculture, Tanta University, Egypt.
18. Mansour MA. 2017. Genetic analysis of earliness and yield component traits in five barley crosses. *Journal of Sustainable Agricultural Science* **43** (**3**): 165-173.
19. Mather K and JL Jinks. 1971. Biometrical Genetics. 2nd edition. Chapman and Hall, London p. 382.
20. Potla KR, SS Bornare, LC Prasad, R Prasad and AH Madakemohekar. 2013. Study of heterosis and combining ability for yield and yield contributing traits in barley (*Hordeum vulgare* L.). *The Bioscan* **8**(**4**): 1231-1235.
21. Prakash V, RV Singh and DD Saini. 2005. Gene action for grain yield and its related traits in barley (*Hordeum vulgare* L.). *Crop Improvement* **32** (**1**): 40-43.
22. Raikwar RS. 2014. Estimation of gene effects for grain yield and its related traits under normal and saline sodic soil in barley (*Hordeum Vulgare* L.). *Triticeae Genomics and Genetics* **5** (**1**): 1-6.
23. Ramage RT. 2011. A History of Barley Breeding Methods. *Plant Breeding Reviews* **5**: 95-138.
24. Rathore RKS and Y Chauhan. 2017. GCA and SCA effects analysis for grain yield and its quantitative traits in six-rowed barley (*Hordeum vulgare* L.) in Agra region. *Indian Journal of Scientific Research* **16** (**1**): 56-63.
25. Sharma Y, SN Sharma, P Joshi and RS Sain. 2002 .Combining ability analysis for yield and yield contributing characters in six-rowed barley. *SABRAO Journal of Breeding and Genetics* **34**(**2**): 55-63.
26. Sharma Z, SN Sharma, RS Joshi and RS Sain. 2003. Combining ability in the F1 and F2 generations of diallel cross in six-rowed barley (*Hordeum vulgare* L). *Acta Agronomica Hungarica* **51**: 281-288.
27. Verma AK, SR Vishwakarma and PK Singh. 2007. Line x Tester analysis in barley (*Hordeum vulgare* L) across environments. *Barley Genetics Newsletter* **37**: 29-33.
28. Vimal SC and SR Vishwakarma. 1999. Gene effects controlling yield components in barley (*Hordeum vulgare* L.) rachis. *Barley and Wheat Newsletter* **18** (**2**): 21-25.
29. Yadav SK.2016. Studies on genetic divergence and combining ability analysis for yield and malting quality traits in barley (*Hordeum vulgare* L.). PhD Thesis JNKVV pp 209.
30. Zhang X, L Lv, C Lv, B Guo and R Xu. 2015. Combining ability of different agronomic traits and yield components in hybrid barley. *PLoS ONE* 10(6):e0126828. doi:10.1371/journal.pone.0126828