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Short Communication

Combining ability and heterosis in forage barley

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High yield with quality is always the most important aim for forage barley breeding. From about 1000 accessions of barley resources, some high yielding and quality barley genotyeps with good synthetic characters, including Supi No. 1 and Pin 8 from Jaingsu province of China, and Clipper from Australia, were selected. These have been examined and approved as spreading varieties in our province, and the genetic studies have been made on their grain, nodal and leaf characters [1-2]. High yield varieties Tequila, 8640 and Mytl 44 of forage barley have also been approved as spreading ones. In order to transfer the beneficial genes of high yield and protein into the spreading varieties and to select new genotypes suitable to Yunnan plateau, we analysed the combining ability from a 10-parent diallel cross to provide useful materials and reference for forage barley breeding and heterosis breeding.

The 10 genotypes of barley namely: (1) Diamond of Canada, (2) Ziguangmangerlin, the high-protein resource of Yunnan (19.9% of protein), (3) 8640 of Mexico, (4) Beate of Germany, (5) Eneldo-s of Mexico, (6) Salva-s of Mexico, (7) Manker of USA, (8) Mytl 44 of USA, (9) 8198 of Bubei, China, and (10) Karnal 15 of India were crossed in half diallel fashion and 45 crosses and their 10 parents were screened in a 3-replicated randomized block design with plots of single row 1 × 0.3 m^2 in YAAS. Main panicles of 5 random plants from each plot were examined for plant height, effective grain number per panicle, grain weight per panicle and 1000- kernel weight. Using the mean of 5 plants, analysis of variance for the above character was carried out to estimate heritability and heterosis in F_1 generation as well as combining ability following Griffing model [3].

The heritability ranged from 56% for 1000-kernel weight, 51.2% for grain weight per panicle; 42.8% for effective grain number per pancile and 37.6% for plant height, (Table 1). The variance of gca was significantly greater than sca variance for plant height, effective grain number and grain weight per panicle showing that these characters were controlled mainly by additive effects of genes. Improved variety is easy to obtain here by cross- breeding and simple selection. The additive and non-additive effects of genes were of equal importance for 1000-kernel weight, showing that the heritability of the 1000-kernel weight of forage barley was less than that of beer barley.

The heritability estimates for plant height, effective grain number, grain weight per panicle and 1000-kernel weight for forage barley are lower than those for beer barley [1], whose grain is small and uniform, but all

Table 1. Heritability estimates, ratio of additive to total genotypic variance and gca effects of parents in forage barley

Character	h%	$\frac{2\sigma^2 g}{2\sigma^2 g + \sigma^2 s}$	Parents									
			1	2	3	4	5	6	7	8	9	10
			gca effect									
Plant height	37.6	5.2	3.40	6.85	-3.22	-3.28	-3.03	2.12	1.23	2.37	-2.41	-4.03
Effective grain number	42.8	2.6	-6.48	-21.56	2.15	1.33	-5.75	-2.91	5.73	20.00	7.94	-1.34
Grain weight per panicle	51.2	3.6	-0.37	-2.76	0.34	-0.71	-1.31	0.69	2.20	3.19	-0.06	0.04
1000-kernel weight	56.0	1.2	-0.12	1.43	0.79	-1.44	-1.20	3.57	1.22	-0.61	-2.55	-1.09

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Table 2. The mean (x), heterosis (h%) and sca effect for four characters in different cross combinations of barley

Combi-nations	Plant height			Effective grain number/panicle			Grain weight/panicle			1000-Kernal weight		
	×(cm)	h%	sca	×	h%	sca	×(g)	h%	sca	×(g)	h%	sca
1×2	107.7	7.0	0.29	131.3	33.6	28.55	4.6	37.3	0.75	35.0	2.6	−3.43
1×3	96.7	11.5	*0.65*	62.3	−42.2	−45.61	3.2	−5.4	−0.68	51.3	64.4	13.51
1×4	101.3	7.8	4.01	135.3	23.4	28.22	3.7	2.8	0.08	27.1	−17.4	−8.46
1×5	95.3	7.1	−2.24	94.3	−9.3	−5.71	3.4	17.7	−0.07	36.3	26.3	0.50
1×6	104.7	9.0	2.01	125.7	17.6	22.85	4.6	28.0	0.63	36.3	7.7	−4.26
1×7	94.7	0.4	−7.10	116.0	18.2	4.51	4.4	25.1	0.06	37.9	5.6	−0.31
1×8	105.3	8.8	2.36	121.0	16.4	−5.66	3.8	15.6	−0.75	31.7	−1.4	−4.69
1×9	101.0	7.4	2.84	77.7	−28.3	−36.00	2.9	−6.0	−0.88	36.7	29.7	2.25
1×10	95.0	7.1	−1.54	94.7	1.2	45.72	3.9	24.1	0.10	40.8	41.9	4.89
2×3	96.7	0.7	−4.10	99.0	15.8	6.18	3.7	31.8	0.15	37.7	10.7	−1.64
2×4	108.3	4.8	7.56	93.0	5.7	1.00	3.7	23.8	0.41	40.1	12.5	2.99
2×5	96.3	−2.0	−4.69	52.8	−35.6	−32.12	2.0	−16.9	−1.14	37.2	17.7	−0.15
2×6	106.7	1.3	0.58	70.7	−16.4	−17.06	3.9	28.2	0.26	54.7	49.5	12.59
2×7	104.3	0.6	−0.95	92.3	21.8	−4.10	3.3	11.2	−0.72	35.7	−7.9	−4.06
2×8	106.0	−0.2	−0.39	113.0	38.4	1.43	4.3	45.8	0.07	35.7	2.0	−2.24
2×9	108.3	4.0	0.89	112.7	31.3	14.09	3.9	57.0	0.45	34.6	11.1	−1.40
2×10	95.0	11.9	−4.99	72.8	−16.8	−16.53	2.5	−1.3	−0.98	34.8	10.1	−2.66
3×4	91.7	2.6	1.03	111.7	−8.6	−4.01	4.2	5.4	0.13	37.6	14.6	1.13
3×5	91.7	8.7	0.78	109.7	−6.1	1.07	3.9	18.0	−0.02	35.9	24.9	−0.81
3×6	102.7	12.4	6.63	121.7	2.0	10.23	4.5	13.0	0.08	37.0	9.8	−4.48
3×7	96.0	7.1	0.81	143.0	29.2	22.89	5.3	34.8	0.51	37.1	3.3	−2.03
3×8	98.3	6.7	1.98	143.3	23.0	7.72	5.6	49.1	0.60	38.8	20.7	1.50
3×9	86.7	−3.9	−4.85	123.3	2.1	0.98	3.7	7.3	−0.53	30.0	6.0	−5.36
3×10	88.3	5.2	−1.64	113.3	−7.4	0.25	4.0	12.2	−0.25	35.0	21.7	−1.83
4×5	85.3	−6.9	−5.56	113.0	−4.7	5.19	3.2	−9.0	−0.45	28.3	−6.8	6.19
4×6	97.7	6.6	1.69	83.0	−31.5	−27.65	3.3	−19.2	−0.85	40.6	15.0	1.35
4×7	100.7	2.0	5.58	102.0	−17.3	3.9	−6.1	−1.5	37.9	1.1	1.0	1.00
4×8	89.0	−10.6	−7.26	143.0	20.0	8.54	5.0	28.5	−1.22	35.4	4.9	0.33
4×9	83.3	−14.5	−8.19	117.0	−4.9	−4.50	4.6	27.5	0.63	39.7	32.8	5.56
4×10	91.0	−5.8	−1.62	122.7	−1.2	10.48	4.4	18.4	0.41	35.9	18.3	1.30
5×6	92.7	−1.1	−3.56	95.7	−17.4	−7.87	4.0	12.8	−0.01	41.5	32.8	2.10
5×7	96.0	4.4	0.63	131.7	22.9	19.47	5.3	48.1	0.92	39.0	16.6	1.86
5×8	100.0	5.2	3.49	127.3	12.7	−0.08	5.1	56.1	0.51	40.1	34.7	4.79
5×9	97.3	5.2	5.56	111.3	−5.1	−3.12	3.7	22.9	−0.12	32.9	27.3	−0.48
5×10	95.7	10.8	5.59	128.3	5.2	23.15	4.2	35.9	0.36	3.3	26.6	−1.54
6×7	99.7	0.7	−0.82	128.3	14.0	13.25	5.0	21.5	0.12	40.0	4.2	−1.90
6×8	99.3	−2.1	−2.36	131.7	14.0	1.48	5.3	34.5	0.21	40.0	15.4	0.08
6×9	92.7	−6.9	−4.19	128.0	4.0	10.74	4.4	22.0	0.08	35.6	15.6	−2.54
6×10	95.3	−2.1	0.04	102.0	−15.9	−5.98	3.8	1.3	0.54	36.9	18.1	−2.17
7×8	96.3	−3.6	−4.47	118.0	10.5	−20.86	4.5	16.4	−0.97	38.1	3.4	0.38
7×9	101.0	3.8	5.00	122.3	10.0	−3.60	4.5	25.6	−0.19	36.8	11.5	1.01
7×10	95.7	4.4	1.33	102.3	20.4	−14.32	5.6	52.7	0.88	41.3	23.5	4.05
8×9	99.0	−1.3	1.86	149.0	27.4	7.93	5.2	52.7	0.30	34.7	18.6	−0.74
8×10	100.3	6.6	4.79	131.0	13.4	−0.80	4.7	34.6	−0.23	34.7	16.8	−0.73
9×10	86.0	−6.7	−4.47	132.3	10.5	13.47	4.4	39.3	0.25	32.7	26.5	−0.79

the characters coordinate well to the varied environment to get a high yield.

The positive and significant heterosis for effective grain number was observed in the 27 combinations, for the grain weight per panicle in 37 combinations and for the 1000-kernel weight in 42 combinations. Crosses between Yunnan Ziguangmangerlin and American, Canadian, Mexican, Hubei of China expressed a lot of heterosis.

The differences between sca effects for different cross combinations are significant (Table 2). Plant height showed positive sca for 24 combinations, effective grain number for 24 combinations, grain weight per panicle for 26 combinations and 1000-kernel weight for 20

combinations. This showed that the varieties with low gca such as Diamond and Karan 15, Yunnan Ziguangmangerlin and 8640, etc. are high in sca in cross estimations.

The gca of parents for plant height varied as 2 > 1 > 8 > 6 > 7 > 9 > 5 > 3 4 > 10, where the numbers 1 to 10 correspond to the genotypes included in half diallel mating. The plant height of Yunnan resource (too high) could be improved by Indian or Mexican varieties. For effective grain number, gca varied as 8 > 9 > 7 > 3 > 4 10 > 6 > 5 > 1 > 2; for grain wieght per panicle as 8 > 7 > 6 > 3 > 10 > 9 > 1 > 4 > 5 > 2; and for 1000 kernel weight as 6 > 2 > 7 > 3 > 1 > 8 > 10 > 5 > 4 > 9. In view of high gca of Myt44 of America it is highly compatible.

Controlled by the additive effect of genes, the plant height in barley is easy to improve by crossing and simple pedigree selection. Therefore, the bad character (too tall) of Yunnan local variety could be improved by using foreign varieties such as Karan 15, Eneldo"s", 8640 etc.

Mytl 44 has large panicle and grain number with good synthesis of characters with high gca; and with higher sca in cross combinations with temperate variety (Diamond), with tropical variety (Karan 15), subtropical variety (Ziguangmangerlin) of Yunnan This shows that the compatability of barley variety maybe correlated with latitude and elevation.

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