Chemical Science Review and Letters ISSN 2278-6783

Research Article

Genetic analysis of F2 generation of diallel crosses in oats (*Avena sativa* L. for forage yield and its contributing traits

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Abstract

Forty five F_1 crosses (excluding reciprocals) were generated through a 10x10 diallel mating design during *rabi* 2013-14 at SKUAST-K, Shalimar. The final experimental material comprised the ten parents and their forty five F_2 segregants (F_{2s}). The experiment was laid out in a randomized block design with three replications. Analysis of variance for general combing ability (GCA) and specific combing ability (SCA) revealed significant mean squares for all the traits studied. The mean squares due to GCA, SCA, and error were used for the estimation of variances attributable to GCA and SCA. Variances due to GCA (σ^2_g) were higher in magnitude than their corresponding SCA variances (σ^2_s) in the individuals for all traits. The estimates of additive genetic variance and dominance variance revealed that magnitude of additive variance was higher than the dominance variance for forage yield and its attributing traits indicating preponderance of additive gene action except for days to 50% flowering, flag leaf length, crude protein content in fodder as well as seed and ash content in leaf. Average degree of dominance (σ^2_D/σ^2_A) revealed preponderance of over dominance for days to 50% flowering, culm diameter, flag leaf length, seed length breadth ratio, crude protein content in seed as well as fodder and ash content in leaf. All other traits showed partial dominance. None of the parents was a good general combiner for all the traits studied. SKO-208, SKO-210, SKO-211 and SKO-213were found to be good combiners for green fodder yield and its contributing traits and seed yielding attributing traits. SKO-208 and SKO-2010 was found to be a good general combiner for most of the traits.

Keywords: Oats, F2 Segregants, GCA, SCA, Forage Yield

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Introduction

Oats ranks sixth in the world cereal production statistics following wheat, maize, rice, barley and sorghum. Oats belongs to family poaceae. Oat grain has always been an important form of livestock feed as a good source of protein, fibre and minerals. Oats remains an important grain crop for people in marginal ecologies, for grain as well as fodder, bedding, hay, silage and livestock grain feed [1]. Hexaploid forms *Avena sativa* and *Avena byzantina* are the commonest source of improved cultivars [2]. Fodder cultivars are usually a by-product of breeding for grain. Livestock grain feed is the primary use of oat crops, accounting for an average of around 74 % of world's total usage in 1991 to 1992 [3]. Oats is better adapted to variable soil types and can perform better on acidic soils than other small grain cereals crops [4]. It is usually grown in cool moist climate and is sensitive to hot, dry weather from head emergence to maturity. For these reasons, world oat production is generally concentrated between latitudes 35°-65°N and longitude 20°-46°S, including Finland and Norway. Modern plant breeding and oat development focuses primarily on oats grown for grain and not for fodder. This development and investment bias toward grain cultivars continues, with few exceptions resulting in very few specific global references on the literature on fodder oats [5]. Despite the extensive use of oats for forage and fodder, very little of plant improvement research resources are devoted to the development of oats especially for fodder uses. Oat (*Avena sativa* L.) is distinct among the cereals due to its multifunctional characteristics and nutritional profile. It is a good source of dietary fibre especially β-glucan, minerals and other nutrients. Oats and its by-products have proven to be helpful in the treatment of diabetes and cardiovascular disorders. Oat bran is a good source of B-complex vitamins, protein, fat, minerals besides heart healthy soluble fibre β-glucan [6]. One of the most common uses is the livestock feed. The protein content of the hulless oat kernel (groat) ranges from 12 to 24 per cent, the highest among cereals [7].

The state of Jammu and Kashmir in general and Kashmir valley in particular is ideally suited for fodder oats cultivation because of its temperate climate. Oats is grown as *Rabi* crop in paddy fields, Karewa lands and orchard areas [8]. In Jammu and Kashmir animal rearing is an important occupation. State livestock population is 7.8 million so the fodder production is not sufficient enough to meet the requirements of a burgeoning livestock population [9]. Cultivation of high yielding fodder oat cultivar Sabzaar developed for temperate climatic conditions of Kashmir Valley has helped in enhancing forage productivity but in order to bridge the gap between demands and supply of green fodder in Kashmir valley there is need to further increase the productivity per unit area [10], thus necessitating development of varieties having higher forage yield potential (>400 q/ha) and better nutritional quality.

The choice of parents for a hybridization programme is a prerequisite for obtaining superior crosses. The common approaches of choosing parents on the basis of their *per se* performance does not necessarily yield fruitful results [11]. On the other hand choosing parents on the basis of their general combining ability (GCA) estimates for components of economic worth and genetic divergence has been reported to be effective. During past few decades, several reports have appeared which indicate that diallel analysis is better method of understanding the generative nature of the inheritance of the traits and to ascertain the prepotency of parents. This is an efficient technique for deriving basic information on parental combinations in terms of their combining ability besides elucidating the nature and magnitude of gene action.

Although F_1 data is mostly used to estimate the genetic parameters as per [12], but it is usually difficult to obtain sufficient F_1 seeds especially for multiplication testing or have enough seeds for replications in self-pollinated crops where hand emasculation must be done. Due to easiness of production of F_2 seeds, many researchers use F_2 generation for diallel analysis to estimate combing ability and other genetic parameters. These researchers also reported that F_2 analysis provide reliable and better information than F_1 generation.

Material and Methods

The present investigation entitled "Genetic analysis of F_2 generation of diallel crosses in oats (*Avena sativa* L.)" was conducted during *rabi* season of 2013-14 at the Mountain Livestock Research Institute, Manasbal to obtain information on various genetic parameters that included extent of genetic variability present in the materials, morphological, agronomic and quality traits, combining ability effects for forage yield and its component traits. The basic materials for the present study consisted of forty five (45) F_2 generation crosses (excluding reciprocals) developed through diallel mating design from ten parents viz: SKO-204, SKO-205, SABZAAR, SKO-207, SKO-208, SKO-209, SKO-210, SKO-211, SKO-212, and SKO-213 selected from the germplasm collection maintained at Division of Plant Breeding and Genetics, SKUAST-K, Shalimar. The observations were recorded on days to 50 per cent flowering, plant height (cm), culm diameter (cm), green fodder yield m^{-1} row (g), dry fodder yield m^{-1} row (g), leaf stem ratio, flag leaf length (cm), no. of tillers m^{-1} row, crude protein content in fodder (%), ash content in leaf (%). The data was subjected to statistical and biometrical analysis to estimate the genetic parameters as per [12].

Result and Discussion

Analysis of variance (**Table 1**) for general and specific combing ability revealed significant mean squares for GCA and SCA for all the traits studied. The mean squares due to GCA, SCA and error were used for the estimation of variances attributable to GCA and SCA. Variances due to GCA (σ^2_g) (**Table 2**) were higher in magnitude than their corresponding SCA variances (σ^2_s) in the individuals for all traits. The estimates of additive genetic variance and dominance variance revealed that magnitude of additive variance was higher than the dominance variance for forage yield and its attributing traits indicating preponderance of additive gene action except for days to 50% flowering, flag leaf length, crude protein content in fodder as well as ash content in leaf. Average degree of dominance (σ^2_D/σ^2_A) revealed preponderance of over dominance for days to 50% flowering, culm diameter, flag leaf length, seed length breadth ratio, crude protein content in fodder and ash content in leaf. All other traits showed partial dominance. None of the parents was a good general combiner for all the traits studied (**Table 3**), SKO-208, SKO-210, SKO-211 and SKO-213 were found to be good combiners for green fodder yield and its contributing traits. SKO-208 and SKO-2010 were found to be a good general combiner for most of the traits.

Table 1 Analysis of variance for combining ability and estimates of components of variance for forage yield and its attributing traits in F_2 segregating generation of oats (*Avena sativa* L.)

Source of variation	d.f	Mean squares									
		Days to 50% flowering	Plant height (cm)	Culm diameter (mm)	Green fodder yield meter^{-1} (g)	Dry fodder yield meter^{-1} (g)	Leaf stem ratio	Flag leaf length (cm)	No. of tillers m^{-1} row	Crude protein content fodder (%)	Ash content (%)
GCA	9	122.552**	258.125**	0.0355**	144127.372**	1761.915**	43.483**	22.45**	641.856**	1.418**	1.196**
SCA	45	26.857**	56.576**	0.0361	3405.930**	201.73**	4.316**	6.490**	81.322**	0.707**	1.121**
Error	108	1.065	23.774	0.0002	64.352	102.128	0.712	1.180	1.740	0.073	0.011

*, **, significant at 5 and 1 per cent levels respectively.

Table 2 Genetic components of variances for forage yield and its attributing characters in F_2 generation in oats

Components of genetic variance	Days to 50% flowering	Plant height (cm)	Culm diameter	Green fodder yield m^{-1}	Dry fodder yield m^{-1}	Leaf stem ratio	Flag leaf length (cm)	No. of tillers m^{-1} row	Crude protein content in fodder (%)	Ash content in leaf (%)
σ^2g	10.124	19.529	0.003	12005.252	138.316	3.564	1.772	53.343	0.112	0.099
σ^2s	25.793	32.801	0.036	3341.578	94.809	3.604	5.310	79.583	0.635	1.110
σ^2e	1.065	23.744	0.0002	64.345	102.128	0.712	1.180	1.740	0.073	0.11
σ^2A	20.248	39.058	0.036	24010.503	276.631	7.129	3.544	106.686	0.224	0.198
σ^2D	25.793	32.801	0.042	3341.578	94.809	3.604	79.583	0.635	1.110	79.583
σ^2D/σ^2A	1.274	0.840	1.167	0.139	0.034	0.506	1.498	0.746	2.835	5.606

*, **, significant at 5 and 1 per cent levels respectively

Table 3 General combining ability effects for forage yield its attributing traits in parent of oats (*Avena sativa* L.)

S. No.	Parents	GCA effects									
		Days to 50% flowering	Plant height (cm)	Culm diameter (cm)	Green fodder yield m^{-1} (g)	Dry fodder yield m^{-1} (g)	Leaf stem ratio	Flag leaf length (cm)	No. of tillers m^{-1} row	Crude protein content leaf (%)	Ash content leaf (%)
1	SKO-204	-1.072**	2.428	-0.019**	-154.219**	-1.347	-0.600*	0.252	-5.178**	0.261**	-0.074**
2	SKO-205	2.761**	-3.397*	-0.023**	-118.158**	-6.792*	-0.452	1.392**	-2.094**	-0.280**	-0.031
3	SABZAAR	-4.156**	1.378	-0.003	32.786**	2.883	-3.451**	0.953**	-5.233**	-0.057	0.510**
4	SKO-207	3.289**	-1.530	0.047**	-12.102**	-1.885	0.727**	0.626*	1.100**	0.153*	-0.229**
5	SKO-208	-0. 850**	-4.466**	0.048**	70.972**	13.173**	4.000**	0.706*	4.017**	0.167*	0.039
6	SKO-209	0.122	0.842	-0.053**	-85.222**	-2.952	0.893**	0.589*	-1.094**	-0.045	-0.429**
7	SKO-210	3.928**	5.587**	0.063**	236.208**	17.442**	0.895**	-0.366	-1.650**	0.495**	0.410**
8	SKO-211	-2.711**	2.792*	-0.010*	31.997**	-5.623*	-0.577*	0.739*	-6.067**	0.319**	0.079**
9	SKO-212	-4.572**	5.451**	-0.112**	0.928	10.335**	-1.285**	-2.591**	-0.706	-0.494**	-0.438**
10	SKO-213	3.261**	-9.086**	-0.043**	-3.190	-25.233**	-0.150	-2.301**	18.906**	-0.520**	0.164**
	SE(gi)	± 0.283	± 1.335	± 0.004	± 2.197	± 2.796	± 0.231	± 0.297	± 0.361	± 0.073	± 0.028
	SE (gi-gj)	± 0.421	± 1.990	± 0.006	± 3.275	± 4.126	± 0.344	± 0.443	± 0.538	± 0.110	± 0.043
Parents with desirable GCA effects		5	3	3	4	3	4	6	3	5	4

*, **, significant at 5 and 1 per cent levels respectively.

The study of SCA effects (**Table 4**) revealed that none of the crosses was a desirable specific combiner for all the traits under study. However, several cross combinations were observed to have highest desirable significant SCA effects for these traits. Desirable cross combinations for days to 50 per cent flowering were SKO-204 X SKO-212 (-13.677), SKO-205 X SKO-212 (-9.510) and SKO-208 X SKO-212 (-10.899) having the highest desirable SCA effects. Desirable significant SCA effects (positive) for increased plant height were exhibited by 3 cross that included SKO-205 X SKO-210, SKO-207 X SKO-212 and SKO-208 X SKO-212. For culm diameter, SKO-204 X SABZAAR, SKO-204 X SKO-207, SKO-204 X SKO-211, exhibited desirable (positive) significant SCA effects. Green fodder yield m^{-1} is an important forage yield trait and the crosses showing desirable SCA effects were SKO-204 X SKO-207, SKO-204 X SKO-208, SKO-204 X SKO-211, SKO-204 X SKO-213, SKO-205 X SKO-208, and SKO-205 X SKO-212. For dry fodder yield m^{-1} row (g), crosses SKO-204 X SKO-205, SKO-204 X SKO-211 showed highest SCA effects. The crosses exhibiting desirable and significant SCA effects for protein content were SKO-204 X SABZAAR and SKO-204 X SKO-210. Most of the crosses for ash content exhibited significant SCA effects but desirable (positive) and significant SCA effects were exhibited by SKO-204 X SABZAAR, SKO-204 X SKO-209, and SKO-204 X SKO-211. For leaf stem ratio, SKO-204 X SKO-207, SKO-205 X SKO-211, SABZAAR X SKO-210 showed significant desirable SCA effects. For flag leaf length the crosses in F_2 generation showing desirable SCA effects were SKO-204 X SKO-209 (3.022), SKO-204 X SKO-210 (3.016), SKO-205 X SKO-209 (3.761) and SKO-212 X SKO-213 (3.627). For no. of tillers m^{-1} row, crosses SKO-208 X SKO-213 (24.399) followed by SKO-209 X SKO-213 (7.177), SKO-210 X SKO-211 (7.038), SKO-210 X SKO-212 (5.677) and SKO-208 X SKO-210 (5.288) showed high SCA effect. The crosses which showed high desirable significant SCA effect for no. of effective tillers m^{-1} row were SKO 204 X SABZAAR, SKO-204 X SKO-209, SKO-204 X SKO- 211. The crosses were mostly the result of high x low or low x low or low x average general combiners (Table 3 and 4).

Table 4 Specific combining ability effects for forage yield its attributing traits in oats (*Avena sativa* L.)

S. No.	Crosses	SCA effects				
		Days to 50% flowering	Plant height (cm)	Culm diameter (cm)	Green fodder yield m^{-1} row (g)	Dry fodder yield m^{-1} row (g)
1	SKO-204 X SKO-205	1.323	2.166	-0.087**	-14.050*	-13.463**
2	SKO-204 X SABZAAR	-0.760	3.358	0.083**	-106.661**	1.361
3	SKO-204 X SKO-207	1.129	-2.834	0.057**	23.361**	1.962
4	SKO-204 X SKO-208	1.268	-3.431	0.021	29.587**	-0.028
5	SKO-204 X SKO-209	2.629**	-0.240	-0.053**	-8.886	-4.903
6	SKO-204 X SKO-210	1.490	-3.217	-0.039**	-9.816	5.502
7	SKO-204 X SKO-211	2.795**	3.744	0.030**	-9.505	14.134*
8	SKO-204 X SKO-212	-13.677**	-3.648	0.092**	18.464**	0.043
9	SKO-204 X SKO-213	-0.510	3.821	0.127**	85.616**	8.811
10	SKO-205 X SABZAAR	-0.593	1.649	0.087**	-22.688**	14.793*
11	SKO-205 X SKO-207	0.962	-3.009	-0.009	5.766	-2.026
12	SKO-205 X SKO-208	3.101**	4.394	-0.044**	18.692**	2.984
13	SKO-205 X SKO-209	1.795*	-2.848	-0.026**	-12.847	2.042
14	SKO-205 X SKO-210	-3.677**	9.041*	-0.028**	-8.177	6.548
15	SKO-205 X SKO-211	-1.371	-2.065	-0.059**	-12.166	10.713*
16	SKO-205 X SKO-212	-9.510**	0.177	0.120**	19.370**	13.055*
17	SKO-205 X SKO-213	2.323**	-3.220	-0.003	73.122**	1.257
18	SABZAAR X SKO-207	5.545**	-13.951**	-0.083**	30.255**	-0.768
19	SABZAAR X SKO-208	1.351	5.719	0.006	36.681**	0.475
20	SABZAAR X SKO-209	-5.288**	0.177	-0.033**	3.942	13.033*
21	SABZAAR X SKO-210	-1.427	0.399	-0.092**	-81.655**	1.572
22	SABZAAR X SKO-211	-5.121**	-4.106	-0.123**	-4.411	1.938
23	SABZAAR X SKO-212	7.407**	-4.798	0.072**	33.892**	-0.087
24	SABZAAR X SKO-213	3.573**	1.471	0.004	90.510**	-2.019
25	SKO-207 X SKO-208	1.573	2.227	-0.060**	-41.498**	2.309
26	SKO-207 X SKO-209	1.934*	-4.815	-0.076**	17.463**	2.201
27	SKO-207 X SKO-210	-0.462	-1.826	-0.138**	35.633**	7.273
28	SKO-207 X SKO-211	-3.232**	1.335	-0.142**	14.544*	9.505
29	SKO-207 X SKO-212	-4.308**	9.510*	-0.037**	-51.953**	-39.520**
30	SKO-207 X SKO-213	-9.205**	3.713	-0.026**	-103.068**	2.382
31	SKO-208 X SKO-209	-0.283	-0.079	-0.223**	28.023**	1.110
32	SKO-208 X SKO-210	1.934*	2.510	-0.206**	42.992**	5.983
33	SKO-208 X SKO-211	-2.760**	2.305	-0.147**	4.203	5.348

34	SKO-208 X SKO-212	-10.899**	11.113*	-0.188**	-262.294**	-10.843*
35	SKO-208 X SKO-213	-2.066*	-37.151**	-0.207**	4.491	-11.842*
36	SKO-209 X SKO-210	-0.371	-0.965	-0.211**	-9.680	2.641
37	SKO-209 X SKO-211	-4.066**	-3.104	-0.099**	-8.536	-1.627
38	SKO-209 X SKO-212	5.129**	-2.395	-0.033*	30.600**	-13.118*
39	SKO-209 X SKO-213	-1.705*	5.508	-0.162**	-25.315**	-0.250
40	SKO-210 X SKO-211	2.462**	-3.381	-0.015	2.967	-63.255**
41	SKO-210 X SKO-212	-5.677**	-7.206	-0.173**	31.170**	7.920
42	SKO-210 X SKO-213	-0.177	2.530	-0.048**	-20.412*	10.389*
43	SKO-211 X SKO-212	-4.371**	4.321	-0.350**	41.681**	8.286
44	SKO-211 X SKO-213	2.795**	-0.809	0.061**	-25.801**	5.721
45	SKO-212 X SKO-213	3.323**	2.666	0.146**	17.769*	6.529
	S. E (sij)	± 0.85	± 4.026	± 0.012	± 6.620	± 5.344
S. E (sij – sik)	± 1.192	± 4.491	± 0.017	± 9.26	± 7.669	± 4.345
	No. of crosses showing desirable SCA effects	**24**	**23**	**13**	**25**	**30**

*, **, significant at 5 and 1 per cent levels respectively

Table 4 continued

S. No.	Crosses	SCA effects				
		Leaf stem ratio	**Flag leaf length (cm)**	**No. of tillers m^{-1} row**	**Crude protein content fodder (%)**	**Ash content leaf (%)**
1	SKO-204 X SKO-205	-3.367**	-0.808	1.593	0.019	-0.746**
2	SKO-204 X SABZAAR	-1.371*	-0.803	3.066**	0.563*	2.005**
3	SKO-204 X SKO-207	2.067**	-2.395*	-0.268	0.236	-1.125**
4	SKO-204 X SKO-208	1.171	1.708	0.816	0.166	-0.140
5	SKO-204 X SKO-209	0.068	3.022**	5.260**	-0.039	0.918**
6	SKO-204 X SKO-210	-0.654	3.016**	-15.851**	0.545*	-1.084**
7	SKO-204 X SKO-211	-0.005	-0.958	2.232*	-1.073**	1.387**
8	SKO-204 X SKO-212	-0.631	1.835*	-0.793	0.796**	-1.140**
9	SKO-204 X SKO-213	-0.079	-1.149	-0.073	-0.544*	-0.021
10	SKO-205 X SABZAAR	1.057	-0.560	0.649	-1.490**	1.483**
11	SKO-205 X SKO-207	-2.208**	-0.483	1.649	0.780**	0.525**
12	SKO-205 X SKO-208	0.889	1.070	-0.268	0.220	-0.916**
13	SKO-205 X SKO-209	-0.570	3.761**	-33.823**	-0.729**	-0.111
14	SKO-205 X SKO-210	-2.252**	1.599	7.066**	0.145	2.267**
15	SKO-205 X SKO-211	3.500**	-0.089	3.149**	-0.442*	-0.809**
16	SKO-205 X SKO-212	-0.456	0.844	2.455*	0.650**	0.057
17	SKO-205 X SKO-213	0.212	0.431	1.177	-0.093	-2.004**
18	SABZAAR X SKO-207	1.025	-3.744**	3.121**	0.660**	-0.110
19	SABZAAR X SKO-208	-0.938	-3.581**	-7.129**	-0.313	0.089
20	SABZAAR X SKO-209	0.549	0.607	3.649**	0.658**	-2.373**
21	SABZAAR X SKO-210	5.967**	2.111*	-0.795	0.235	0.598**
22	SABZAAR X SKO-211	-0.008	2.141*	-7.725**	0.215	0.126
23	SABZAAR X SKO-212	-1.133	0.740	-0.740	0.957**	1.556**
24	SABZAAR X SKO-213	-1.515*	-1.970*	2.316*	-1.806**	-1.296**
25	SKO-207 X SKO-208	-0.654	0.717	-10.795**	-0.384	-0.348**
26	SKO-207 X SKO-209	0.861	0.714	3.649**	0.125	-1.637**
27	SKO-207 X SKO-210	-1.718*	1.842*	3.871**	0.799**	0.877**
28	SKO-207 X SKO-211	1.981**	-1.496	-5.712**	-0.246	-0.252*
29	SKO-207 X SKO-212	2.665**	-0.399	0.260	-0.913**	1.025**

30	SKO-207 X SKO-213	-0.237	-2.356**	-1.351	-1.896**	-0.067
31	SKO-208 X SKO-209	0.411	0.870	-5.934**	-0.846**	0.198*
32	SKO-208 X SKO-210	0.572	-3.138**	5.288**	-0.965**	0.970**
33	SKO-208 X SKO-211	-5.213**	-3.109**	-1.629	0.201	-0.100
34	SKO-208 X SKO-212	-0.971	2.887**	-3.990**	-0.397	-0.143
35	SKO-208 X SKO-213	-1.213	-2.403**	24.399**	0.580**	1.035**
36	SKO-209 X SKO-210	-3.213**	1.379	3.732**	-0.743**	-0.003
37	SKO-209 X SKO-211	1.009	0.188	3.149**	-0.148	0.088
38	SKO-209 X SKO-212	0.027	-6.279**	2.788*	-1.652**	0.122
39	SKO-209 X SKO-213	1.634*	2.914**	7.177**	0.422	0.553**
40	SKO-210 X SKO-211	-2.347**	1.629	7.038**	0.413	-0.684**
41	SKO-210 X SKO-212	1.654*	-3.541**	5.677**	-0.025	-1.167**
42	SKO-210 X SKO-213	3.142**	-3.231**	-28.601**	0.882**	-0.285**
43	SKO-211 X SKO-212	1.740*	0.715	-1.240	-0.579*	-0.953**
44	SKO-211 X SKO-213	1.461*	-1.336	-2.851**	0.928**	1.495**
45	SKO-212 X SKO-213	-0.384	3.627**	-2.545*	-0.713**	-0.351**
46	S. E (sij)	± 0.696	± 0.897	±1.089	± 0.223	± 0.087
47	S. E (sij – sik)	± 0.974	±1.254	±1.523	± 0.311	± 0.121
48	No. of crosses showing desirable SCA effects	**21**	**24**	**26**	**23**	**20**

*, **, significant at 5 and 1 per cent levels respectively

Table 5 Best parents and F_2 segregating generation identified on the basis of gca and sca effects of forage yield trait in oats

Trait	Parents	GCA	Crosses	SCA	GCA effects of parents
Days to 50% flowering	SKO-204	-1.072	SKO-204 X SKO-212	-13.677	High X High
	SKO-207	3.289	SKO-208 X SKO-212	-10.899	High X High
	SKO-208	-0.850	SKO-207 X SKO-213	-9.205	Low X Low
Plant height (cm)	SKO-205	-3.397	SKO-208 X SKO-212	11.113	Low X High
	SKO-207	-1.530	SKO-207 X SKO-212	9.510	Average X High
	SKO-208	-4.466	SKO-205 X SKO-210	9.041	Low X High
Culm diameter (cm)	SKO-204	-0.019	SKO-204 x SKO-213	0.127	Low X Low
	SKO-205	-0.003	SKO-205 x SKO-212	0.120	Low X Low
	SABZAAR	-0.023	SKO-212 x SKO-213	0.146	Low X Low
Green forage yield m^{-1} row (g)	SKO-204	-154.219	SABZAAR X SKO-213	90.510	High X Average
	SKO-205	-118.158	SKO-205 X SKO-213	73.122	Low X Average
	SABZAAR	32.786	SKO-208 X SKO-210	42.992	High X High
	SKO-207	-12.102	SKO-207 X SKO-210	35.633	Low X High
	SKO-208	70.872	SKO-211 X SKO-212	41.681	High X Average
Leaf stem ratio	SKO-204	-0.600	SABZAAR X SKO-210	5.967	Low X High
	SKO-205	-3.542	SKO-210 X SKO-213	3.142	High X Average
	SABZAAR	-0.452	SKO-207 X SKO-212	2.665	High X Low
Flag leaf length (cm)	SKO-204	0.252	SKO-205 X SKO-209	3.761	High X Average
	SKO-205	1.392	SKO-212 X SKO-210	3.627	Low X Low
	SKO-209	0.589	SKO-204 X SKO-209	3.022	Average X Average
No. of tillers m^{-1} row	SKO-205	-5.178	SKO-208 X SKO-213	24.399	High X High
	SKO-208	4.017	SKO-209 X SKO-213	7.177	Low X High
	SKO-209	-1.094	SKO-210 X SKO-211	7.038	Low X Low
. Crude protein content fodder (%)	SKO-205	-0.280	SABZAAR X SKO-212	0.957	Average X Low
	SABZAAR	-0.057	SKO-211 X SKO-213	0.928	High X Low
	SKO-207	0.153	SKO-210 X SKO-213	0.882	High X Low
Ash content leaf (%)	SKO-204	-0.074	SKO-205 X SKO-210	2.267	Average X High
	SKO-205	-0.031	SKO-204 X SABZAAR	2.005	Low x High
	SABZAAR	0.510	SABZAAR X SKO-212	1.556	High X Low

The study demonstrated that both additive (fixable) and non-additive (non-fixable) components of genetic variance were involved in governing the inherence of almost all the traits under study, although additive genetic variance was predominant for most of the characters. Therefore, bi-parental mating and/or diallel selective mating, which may allow intermating of the selections in different cycles and exploitation of both additive and non-additive gene effects could be useful in the genetic improvement of forage yield characters of oats. Similar results were reported by different researchers in various studies. [13] from a study on combining ability and gene action for yield per plant and its components traits (estimated in an 8 x 8 F_2 half diallel set) showed high significant variance due to general and specific combining ability for nine quantitative characters. The predominance of additive genetic variance was observed for plant height, spike length and sedimentation value, β-carotene content and protein content. Days to 50% flowering, days to 80% maturity and productive tillers per plant exhibited more of non-additive genetic variance. [14] Crossed five wheat cultivars-Cross adl, Marvdast, Chamran, Shiraz and Darab2 for producing one way diallel crosses that were analysed using two models of [12]

In order to synthesize a dynamic population with most of the favourable genes accumulated, it will be pertinent to select the parents which are good general combiners for several characters, in a multiple crossing program [15]. Apart from conventional breeding methods that depend only on additive or additive x additive type of gene action, population improvement can also be promising alternative. Diallel selective mating system [16], for example, is good technique which delays the fixation of gene complexes, permits breakdown of linkages, fosters recombination, and concentrates favourable genes/gene complexes in to a central gene pool by a series of multiple crosses. Normally, the SCA effects do not contribute tangibly to the improvement of self-fertilizing crops, except where commercial exploitation of heterosis is feasible. The SCA represents the dominance and epistasis interaction which can be related to heterosis. However, in self-pollinated crops, the additive x additive type of interaction component is fixable in later generation. Breeder's interest, therefore, vests in obtaining transgressive segregants through crosses and producing more potent homozygous lines. The superiority of the hybrids might not indicate their ability to yield transgressive segregants; rather the SCA would provide a satisfactory criterion [17]. It is therefore suggested that SCA performance may be considered as a criterion for selecting the best crosses. It may also be worthwhile to attempt bi-parental mating among selected crosses in the advanced generation to permit superior recombination [18].

Conclusion

Inclusion of F_2 hybrids showing high SCA and having parents with good gca in to multiple crosses could prove to be a worthwhile approach for tangibly advancing the forage breeding of oats. The parents and desirable cross combinations with superior quality characteristics must be taken in to consideration for further breeding programmes. Promising genotypes like SKO-208, SKO-210, SKO-211, SKO-211 and SKO-213 could be the source of elite alleles based on their GCA, SCA effects and *per se* performance and could be utilised extensively in hybridisation program to accelerate the pace of genetic improvement of forage yield.

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Publication History
Received 20th Oct 2018
Revised 28th Nov 2018
Accepted 04th Dec 2018
Online 30th Dec 2018