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RESEARCH ARTICLE

Genetic analysis of elite China aster hybrids for growth and yield traits in early generations

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Abstract

The present study was undertaken to assess the genetic variability, heritability and genetic advance in F_1 and F_2 generations of ten China aster (*Callistephus chinensis*) hybrids developed through line × tester mating design. A comprehensive evaluation of growth, floral and yield-related traits was conducted to understand the extent of variability and inheritance patterns. Significant differences were observed among hybrids for all the studied traits. High phenotypic and genotypic coefficients of variation (PCV and GCV), coupled with high heritability (>90 %) and genetic advance, were recorded for plant height, plant spread, number of branches per plant, flower diameter, number of flowers per plant and flower yield per plant and per hectare. Particularly, hybrids H_4, H_5 and H_6 showed superior performance in both generations, indicating their potential for further selection and genetic improvement. The F_2 generation exhibited increased variability due to segregation, with higher expression of additive gene action. Yield and floral traits, especially the number of flowers, flower diameter and flower weight, demonstrated high heritability and genetic advance, suggesting scope for effective selection. The study concludes that traits governed by additive genetic control can be improved through simple selection in segregating populations and promising hybrids identified can be utilised in future breeding programs aimed at improving China aster productivity and floral quality.

Keywords: China aster; GCV; growth; heritability; hybrids; PCV; yield

Introduction

Flowers have held cultural and practical significance throughout human history, with floriculture evolving into a dynamic and promising branch of horticulture. In addition to its aesthetic contribution, floriculture plays a crucial socio-economic role by generating employment year-round and contributing to foreign exchange revenues. The increasing popularity of flowers has positioned floriculture as a key growth area and vital commercial domain within horticulture. Factors such as urbanisation, changing lifestyles and the rise of corporate culture have fuelled its expansion. Furthermore, economic liberalisation and supportive government policies have motivated Indian entrepreneurs to invest in this sector. As per the National Horticulture database published by the National Horticulture Board, during 2023-24, the area under floriculture production in India was 285000 ha with a production of 2284000 t of loose flowers and 947000 t of cut flowers. Among traditional flowers cultivated for both loose and cut use, China aster has gained popularity among small and marginal farmers across India due to its ease of cultivation (1).

China aster (*Callistephus chinensis* Nees.), a member of the Asteraceae family, is a significant commercial flower crop. It has gained prominence for its ornamental value and diverse utility. It is a diploid species (2n=18) native to China. The genus name, *Callistephus*, originates from the Greek words *Kalistos* (most beautiful) and *Stephus* (a crown or flower head). Initially classified as

Aster chinensis by Linnaeus, it was later renamed to *Callistephus chinensis* (2). Since its introduction to Europe and other tropical regions in the 18th century, the China aster has emerged as a globally significant ornamental crop (3). Internationally, China aster holds significant ornamental value and is commercially cultivated in countries like Russia, Japan, North America, Switzerland and various European nations. In India, it is predominantly grown by small and marginal farmers in states such as Karnataka, Tamil Nadu, Maharashtra, Andhra Pradesh and West Bengal. This reflects the crops' adaptability to diverse agro-climatic conditions. Karnataka accounts for the highest production, with cultivation centred in districts like Bangalore, Tumkur, Kolar, Chikkaballapur and Belagavi. The crop is cultivated over 207 ha, yielding 1448 Mt with a productivity of 7.01 t/ha, generating an annual income of ₹430 lakhs (6). Yields vary depending on the season and management practices.

As an annual plant, China aster displays hispid, hairy stems with growth habits that can be erect, semi-erect or spreading. Leaves are arranged alternately and vary from broadly ovate to triangular ovate with deep, irregular margins. Based on plant height, it is categorised as short (20-40 cm), medium (40-60 cm), or tall (above 60 cm). The species produces vibrant, solitary flower heads (capitula) composed of pistillate ray florets and hermaphroditic disc florets. The floral biology of the China aster was investigated, revealing that the extent of doubleness in flowers is determined by the ratio of ray to disc florets. The stamens and pistils within individual flowers exhibit asynchronous maturation; the stigma becomes receptive only after pollen is shed (4). However, remaining pollen in the capitulum enables self-pollination, classifying the species as geitonogamous. Consequently, China aster is primarily a self-pollinated plant. This crop flourishes under open-field conditions, enabling consistent flower availability during both *Kharif* and *Rabi* seasons. Its widespread appeal is attributed to a broad colour range and extended vase life. It is widely used for garlands, bouquets, floral arrangements and exhibitions. Dwarf, branched varieties are especially favoured for bedding, herbaceous borders and landscaping purposes (5). Its mass blooming enhances the ornamental value of garden landscapes.

The development of China aster varieties in India began with the breeding efforts that were done in 1990. These early efforts laid the foundation for structured varietal improvement programs in the country. Research institutions such as the Indian Institute of Horticultural Research (IIHR), Bengaluru and the Ganesh Khind Botanical Garden, Pune, have significantly contributed to varietal improvement. The IIHR has developed a series of varieties under the Arka prefix, including Arka Poornima, Arka Kamini, Arka Shashank, Arka Adya, Arka Archana, Arka Advika, Arka Nirali, Arka Shubhi and Violet Cushion. Mahatma Phule Krishi Vidyapeeth, Rahuri, has released Phule Ganesh White, Phule Ganesh Pink, Phule Ganesh Violet and Phule Ganesh Purple, while University of Horticultural Sciences, Bagalkot, has introduced the Krishnaprabha Chinmay variety. The ornamental plant industry is ever-evolving, necessitating constant varietal innovations. In this dynamic context, current commercial China aster cultivars in India are characterised by semi-double flowers with visible central disks, short stalks and relatively limited vase life. Thus, breeding objectives now focus on enhancing traits such as plant height, branching, flower size and yield, flower colour, stalk length and vase life to improve the crops' suitability for both cut and loose flower markets. Successful breeding strategies hinge on exploiting genetic variability through systematic selection methods. This variability is often more pronounced in early segregating generations. Since the phenotypic expression of traits results from both genetic makeup and environmental influences, a comprehensive understanding of genetic variance, including its additive (heritable) and non-additive components (dominance and epistasis) is critical. Improving selection efficiency requires a detailed assessment of phenotypic variation using parameters such as heritability, genetic advance and both phenotypic and genotypic coefficients of variation. The preliminary experiment was conducted to assess the agronomic performance and genetic variability in newly developed China aster hybrids.

Materials and Methods

The study was conducted at the Floriculture Unit, Department of Horticulture, University of Agricultural Sciences, GKVK Campus, Bengaluru, during the *Rabi* season of 2023-24. A total of twenty-seven hybrids were developed using the Line × Tester mating design and were evaluated for genetic variability and agronomic performance (7). Based on superior expression of agronomic traits and genetic parameters, ten promising hybrids were selected for advancement to the F_2 generation. These selected hybrids were subsequently evaluated for genetic parameters of different growth and yield contributing traits. The experiment was laid out in a Randomised Complete Block Design (RCBD) with three replications and eleven treatments. The details of the genotypes are given in Table 1.

Table 1. Details of genotypes and cross combinations

Hybrid	Cross combination (Parentage)
Hybrid 1	Arka Poornima × P. G. Purple
Hybrid 2	P. G. Pink × Arka Kamini
Hybrid 3	P. G. Pink × A.A.C - 1
Hybrid 4	Arka Poornima × A.A.C - 1
Hybrid 5	P. G. Pink × P. G. Purple
Hybrid 6	P. G. White × P. G. Purple
Hybrid 7	Miraj Local × A.A.C - 1
Hybrid 8	P. G. White × A.A.C - 1
Hybrid 9	Miraj local × P. G. Purple
Hybrid 10	Arka Poornima × Arka Kamini

Observations recorded

Growth parameters

About vegetative growth of the plants, plant height (cm), number of branches per plant and plant spread (cm) were recorded at 30, 60 and 90 days after transplanting.

Yield parameters

With respect to yield, number of flowers per plant, individual flower weight (g), 100-flowers weight (g), flower yield per plant (g) and flower yield per hectare (t) were recorded and analysed. The recorded data were used to compute genetic parameters, such as mean, PCV, GCV, heritability and genetic advance (25). The extent of genetic variability was interpreted based on these computed parameters.

Results and Discussion

The growth parameters were recorded at 30, 60 and 90 days after transplanting and analysed for significant variations. The results are as follows.

Plant height (cm)

At 30 days after transplanting (DAT), plant height in the F_1 generation ranged from 19.14 cm (H_7) to 28.31 cm (H_1). Heritability was 1.000

Table 2. Genetic analysis of China aster hybrids for plant height at different growth stages in early generations

Generation	F_1 generation														
GS	30 DAT					60 DAT					90 DAT				
Parameter	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA
H_1	28.310	0.321	0.321	1.000	6.213	44.930	0.510	0.510	1.000	9.861	51.220	0.581	0.581	1.000	11.241
H_2	25.770	0.292	0.292	1.000	5.656	44.170	0.501	0.501	1.000	9.694	50.420	0.572	0.572	1.000	11.065
H_3	25.090	0.285	0.285	1.000	5.506	43.030	0.488	0.488	1.000	9.444	48.540	0.551	0.551	1.000	10.653
H_4	23.800	0.270	0.270	1.000	5.223	41.830	0.475	0.475	1.000	9.180	48.490	0.550	0.550	1.000	10.642
H_5	28.190	0.320	0.320	1.000	6.187	41.730	0.474	0.474	1.000	9.158	48.030	0.545	0.545	1.000	10.541
H_6	26.260	0.298	0.298	1.000	5.763	40.770	0.463	0.463	1.000	8.948	47.450	0.539	0.539	1.000	10.414
H_7	19.140	0.217	0.217	1.000	4.201	35.850	0.407	0.407	1.000	7.868	43.390	0.492	0.492	1.000	9.523
H_8	22.770	0.258	0.258	1.000	4.997	36.440	0.414	0.414	1.000	7.997	41.940	0.476	0.476	1.000	9.204
H_9	27.270	0.310	0.310	1.000	5.985	40.920	0.464	0.464	1.000	8.981	46.870	0.532	0.532	1.000	10.286
H_{10}	22.950	0.260	0.260	1.000	5.037	39.270	0.446	0.446	1.000	8.618	46.250	0.525	0.525	1.000	10.150
Generation	**F_2 generation**														
GS	30 DAT					60 DAT					90 DAT				
Parameter	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA
H_1	12.532	20.748	0.115	0.554	2.969	66.789	9.647	0.074	0.770	10.222	78.190	12.925	0.114	0.881	18.344
H_2	11.869	21.743	0.134	0.616	3.274	48.127	10.641	0.063	0.592	6.244	65.720	13.016	0.109	0.839	14.793
H_3	12.539	17.343	0.078	0.451	2.019	44.873	13.060	0.095	0.727	8.776	75.521	14.347	0.128	0.892	19.904
H_4	11.000	18.262	0.039	0.216	0.893	54.343	13.937	0.116	0.834	13.010	69.091	15.790	0.142	0.900	20.230
H_5	11.499	26.004	0.187	0.717	4.420	62.575	10.291	0.080	0.774	10.269	68.132	13.348	0.117	0.876	16.411
H_6	12.694	17.043	0.063	0.370	1.649	57.235	12.526	0.107	0.854	12.616	68.577	13.359	0.117	0.877	16.557
H_7	12.209	13.734	0.024	0.174	0.602	61.162	16.162	0.149	0.923	18.792	71.105	16.992	0.157	0.922	22.953
H_8	10.767	17.737	0.042	0.235	0.923	41.018	12.722	0.081	0.636	6.834	64.606	13.519	0.117	0.863	15.531
H_9	13.543	15.103	0.021	0.141	0.595	67.242	18.245	0.173	0.949	23.991	83.570	14.259	0.143	1.000	24.548
H_{10}	12.470	16.319	0.037	0.225	0.943	48.226	14.505	0.145	1.000	14.410	66.061	13.134	0.131	0.997	17.819

GS - Growth stage, DAT - Days after transplanting, PCV - Phenotypic coefficient of variation, GCV - Genotypic coefficient of variation, h^2 - Heritability, GA - Genetic advance

and GA ranged up to 6.213 (H_1). In contrast, the F_2 generation height ranged from 5.89 cm (H_1) to 9.92 cm (H_3), with higher variability (H_3: PCV = GCV = 0.113, Heritability = 1.000, GA = 2.177), suggesting effective segregation and selection potential (Table 2). For the same trait, the observations made at 60 DAT indicate, in F_1, heights ranged from 10.641 cm (H_2) to 18.245 cm (H_9). PCV and GCV ranged from 0.063 to 0.173 and 0.592 to 0.949, respectively. GA was highest in H_9 (23.991), marking it as the most variable and heritable hybrid. In F_2 values showed broader variation: PCV up to 0.260, GCV 0.953 (H_4) and GA reaching 5.030 (H_3), again confirming the presence of additive genes. The data about 90 DAT revealed F_1 hybrids had mean between 12.925 (H_1) and 16.992 (H_7). H_7 showed the highest GCV (0.922) and GA (22.953). Whereas F_2 hybrids displayed a range of 11.40 (H_8) to 26.59 (H_2), with heritability at 1.000 across all hybrids. Maximum GA was observed in H_2 (9.237). These results suggest that high heritability and GCV across stages indicate strong genetic control, with H_3, H_4, H_7 and H_9 emerging as promising hybrids for plant height improvement. Research indicates that similar observations in China aster (8, 9) and in African marigold (10).

Plant spread (cm)

As per Table 3, plant spread at 30 DAT in the F_1 generation ranged from 13.26 cm (H_7) to 20.91 cm (H_5), with H_5 showing PCV = 0.194, GCV = 0.927 and GA = 4.419. While in F_2 generation, H_2 recorded the highest mean (14.97 cm), PCV (0.170), GCV (0.170), Heritability (1.000) and GA (3.285) for the trait. Similarly at 60 DAT, the F_1 hybrids such as H_2 (GCV = 0.924, GA = 5.625) and H_4 (GCV = 0.891, GA = 6.105) showed significant variation. While in F_2 data mirrored this, with H2 again showing high GA (6.797) and heritability = 1.000. The highest plant spread at 90 DAT in the F_1 generation was recorded in hybrid H4 (F_1), which exhibited the maximum GA (8.300) and GCV (0.429). Whereas in F_2, maximum GA was 16.642 (H_8), with heritability (1.000) and GCV (0.389). Strong heritability and GA values make H_4 and H_8 ideal for selection for wider plant spread. Research indicates that similar findings were reported in China aster (11), Marigold (12) and Gerbera (13).

Number of branches per plant

The data about the number of branches per plant of both F_1 and F_2 generations are presented in Table 4. It is evident that at 30 DAT, number of branches in F_1 ranged from 3.50 (H_2) to 4.91 (H_5). Heritability = 1.000 for all hybrids. H_5 had the highest GA (1.078). While F_2 followed similar trends: H_5 highest mean (4.91), GA (1.078) and heritability (1.000). From the data recorded at 60 DAT and 90 DAT, it is clear that GCV and GA increased over time in both generations. At 90 DAT, GA ranged from 0.285 (H_4) to 0.389 (H_5). Whereas in F_2, GA reached 0.294 (H_6) and heritability remained at 1.000, indicating steady trait expression across generations. Research signifies that additive variance dominates; hence, recurrent selection in F_2 will improve branching. Similar outcomes were noticed in previous experimental findings in China aster (14), Chrysanthemum (15) and Marigold (16).

Flowering parameters

In the F_1 generation, the number of flowers per plant ranged from 45.07 (H_5) to 64.26 (H_4), with heritability = 1.000 across hybrids (Table 5). H_4 recorded the highest GA (14.103) and GCV (0.729). Similarly, in the F_2 generation also H_4 recorded the maximum number of flowers per plant (85.333), but the F_2 generation showed slightly higher variability due to segregation, with GA 12.441 (H_2) and 11.539 (H_{10}) and heritability was still close to unity. Research indicates that very high heritability and GA in H_4 and H_{10} imply suitability for direct selection. Similar results for the trait were reported in China aster (17), Dahlia (18), spray chrysanthemum (15) and French marigold (19).

Flower weight and 100-flowers weight

In F_1, individual flower weight ranged from 3.42 g (H_{10}) to 4.91 g (H_5). For the same trait highest GCV (0.056) and GA (1.078) were recorded in H_5 (Table 5). While in F_2, H_{10} showed the highest GA (0.751) and H_5 again recorded the maximum value for individual flower weight (5.167 g). 100-flower weight followed similar trends: the highest GA was noticed in H_1 (68.471) in the F_1 generation and H_2 (75.039) in the F_2 generation, with maximum heritability 1.000 in both generations.

Table 3. Genetic analysis of China aster hybrids for plant spread at different growth stages in early generations

Generation	F_1 generation														
GS	30 DAT					60 DAT					90 DAT				
Parameter	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA
H_1	13.420	0.152	0.152	1.000	2.945	20.850	0.237	0.237	1.000	4.576	25.380	0.288	0.288	1.000	5.570
H_2	14.970	0.170	0.170	1.000	3.285	25.630	0.291	0.291	1.000	5.625	30.970	0.352	0.352	1.000	6.797
H_3	19.880	0.226	0.226	1.000	4.363	32.750	0.372	0.372	1.000	7.187	39.940	0.453	0.453	1.000	8.765
H_4	17.560	0.199	0.199	1.000	3.854	31.680	0.360	0.360	1.000	6.953	37.820	0.429	0.429	1.000	8.300
H_5	17.540	0.199	0.199	1.000	3.849	30.180	0.343	0.343	1.000	6.623	35.170	0.399	0.399	1.000	7.719
H_6	16.480	0.187	0.187	1.000	3.617	29.120	0.331	0.331	1.000	6.391	32.780	0.372	0.372	1.000	7.194
H_7	15.270	0.173	0.173	1.000	3.351	25.440	0.289	0.289	1.000	5.583	28.690	0.326	0.326	1.000	6.296
H_8	14.420	0.164	0.164	1.000	3.165	28.860	0.328	0.328	1.000	6.334	34.310	0.389	0.389	1.000	7.530
H_9	16.090	0.183	0.183	1.000	3.531	28.220	0.320	0.320	1.000	6.193	32.450	0.368	0.368	1.000	7.122
H_{10}	12.530	0.142	0.142	1.000	2.750	26.860	0.305	0.305	1.000	5.895	30.220	0.343	0.343	1.000	6.632
Generation	F_2 generation														
GS	30 DAT					60 DAT					90 DAT				
Parameter	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA
H_1	16.723	24.108	0.220	0.914	7.590	30.772	11.581	0.067	0.583	4.279	50.590	16.723	0.153	0.912	15.894
H_2	16.755	24.460	0.226	0.924	7.798	32.160	12.117	0.083	0.683	5.480	49.980	16.415	0.150	0.913	15.431
H_3	18.790	16.223	0.140	0.863	5.417	32.267	12.071	0.087	0.717	5.756	51.183	14.636	0.132	0.905	13.964
H_4	18.884	17.620	0.157	0.891	6.105	34.433	13.459	0.105	0.782	7.461	57.187	11.841	0.102	0.862	12.030
H_5	15.372	17.092	0.138	0.807	4.366	34.050	9.207	0.044	0.474	3.061	47.077	10.665	0.080	0.754	7.799
H_6	15.466	15.043	0.127	0.842	4.037	32.917	16.112	0.140	0.869	9.497	48.853	14.508	0.131	0.903	13.187
H_7	18.322	11.935	0.119	1.000	4.504	34.033	11.957	0.120	1.000	8.383	45.612	12.772	0.128	1.000	12.001
H_8	16.929	14.597	0.146	1.000	5.091	32.367	11.244	0.112	1.000	7.497	52.013	15.532	0.155	1.000	16.642
H_9	16.237	21.340	0.145	0.678	4.842	32.693	13.492	0.097	0.721	6.554	50.233	13.548	0.135	1.000	14.019
H_{10}	17.469	19.479	0.126	0.647	4.535	30.520	14.738	0.105	0.715	6.621	48.073	12.718	0.127	1.000	12.594

GS - Growth stage, DAT - Days after transplanting, PCV - Phenotypic coefficient of variation, GCV - Genotypic coefficient of variation, h^2 - Heritability, GA - Genetic advance

Table 4. Genetic analysis of China aster hybrids for the number of branches per plant at different growth stages in early generations

Generation	F_1 generation														
GS	30 DAT					60 DAT					90 DAT				
Parameter	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA
H_1	5.890	0.067	0.067	1.000	1.293	11.420	0.130	0.130	1.000	2.506	14.950	0.170	0.170	1.000	3.281
H_2	7.380	0.084	0.084	1.000	1.620	14.050	0.159	0.159	1.000	3.083	19.180	0.218	0.218	1.000	4.209
H_3	9.920	0.113	0.113	1.000	2.177	16.880	0.192	0.192	1.000	3.705	22.920	0.260	0.260	1.000	5.030
H_4	8.950	0.102	0.102	1.000	1.964	15.260	0.173	0.173	1.000	3.349	19.650	0.223	0.223	1.000	4.312
H_5	8.540	0.097	0.097	1.000	1.874	14.930	0.169	0.169	1.000	3.277	17.730	0.201	0.201	1.000	3.891
H_6	8.640	0.098	0.098	1.000	1.896	13.520	0.153	0.153	1.000	2.967	18.250	0.207	0.207	1.000	4.005
H_7	7.470	0.085	0.085	1.000	1.639	12.140	0.138	0.138	1.000	2.664	16.970	0.193	0.193	1.000	3.724
H_8	6.390	0.073	0.073	1.000	1.402	11.150	0.127	0.127	1.000	2.447	15.290	0.174	0.174	1.000	3.356
H_9	6.150	0.070	0.070	1.000	1.350	8.760	0.099	0.099	1.000	1.923	14.560	0.165	0.165	1.000	3.195
H_{10}	7.650	0.087	0.087	1.000	1.679	12.570	0.143	0.143	1.000	2.759	16.260	0.185	0.185	1.000	3.568
Generation	F_2 generation														
GS	30 DAT					60 DAT					90 DAT				
Parameter	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA
H_1	5.936	22.760	0.178	0.783	2.180	13.264	19.189	0.162	0.845	3.793	17.666	12.473	0.070	0.560	4.377
H_2	5.360	29.075	0.251	0.864	2.773	13.652	18.129	0.154	0.852	4.868	16.805	26.590	0.245	0.921	9.237
H_3	5.870	24.856	0.223	0.896	2.695	13.655	13.393	0.094	0.699	3.882	22.200	18.613	0.170	0.912	7.291
H_4	7.027	30.318	0.289	0.953	4.183	14.722	18.100	0.157	0.869	4.593	27.867	15.427	0.142	0.922	8.725
H_5	4.977	26.074	0.226	0.866	2.314	13.746	20.905	0.194	0.927	4.419	15.867	15.740	0.122	0.777	7.069
H_6	5.870	24.856	0.219	0.883	2.653	13.690	19.248	0.172	0.892	4.876	18.267	17.977	0.158	0.876	8.801
H_7	5.947	25.550	0.256	1.000	3.130	13.742	13.262	0.100	0.757	4.826	16.925	12.307	0.080	0.650	6.467
H_8	4.947	23.512	0.235	1.000	2.396	14.229	18.376	0.184	1.000	4.936	16.400	11.400	0.114	1.000	10.167
H_9	6.870	25.108	0.186	0.742	2.637	14.322	15.713	0.108	0.688	3.828	16.147	17.816	0.155	0.870	6.859
H_{10}	6.778	27.626	0.196	0.710	2.741	14.506	20.502	0.164	0.798	4.505	14.194	13.683	0.094	0.684	6.350

GS - Growth stage, DAT - Days after transplanting, PCV - Phenotypic coefficient of variation, GCV - Genotypic coefficient of variation, h^2 - Heritability, GA - Genetic advance

Table 5. Genetic analysis of China aster hybrids for yield contributing traits in early generations

Generation	F_1 generation														
Trait	Number of flowers per plant					Individual flower weight (g)					100-flowers weight (g)				
Parameter	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA
H_1	41.940	0.476	0.476	1.000	9.204	4.330	0.049	0.049	1.000	0.950	311.99	3.541	3.541	1.000	68.471
H_2	56.690	0.643	0.643	1.000	12.441	3.500	0.040	0.040	1.000	0.768	341.92	3.881	3.881	1.000	75.039
H_3	60.030	0.681	0.681	1.000	13.174	4.220	0.048	0.048	1.000	0.926	319.21	3.623	3.623	1.000	70.055
H_4	64.260	0.729	0.729	1.000	14.103	4.280	0.049	0.049	1.000	0.939	336.81	3.823	3.823	1.000	73.918
H_5	45.070	0.512	0.512	1.000	9.891	4.910	0.056	0.056	1.000	1.078	371.12	4.212	4.212	1.000	81.448
H_6	45.200	0.513	0.513	1.000	9.920	4.200	0.048	0.048	1.000	0.922	310.88	3.528	3.528	1.000	68.227
H_7	46.000	0.522	0.522	1.000	10.095	4.530	0.051	0.051	1.000	0.994	362.76	4.117	4.117	1.000	79.613
H_8	50.840	0.577	0.577	1.000	11.158	4.180	0.047	0.047	1.000	0.917	320.75	3.641	3.641	1.000	70.393
H_9	43.610	0.495	0.495	1.000	9.571	4.430	0.050	0.050	1.000	0.972	352.49	4.001	4.001	1.000	77.359
H_{10}	52.580	0.597	0.597	1.000	11.539	3.420	0.039	0.039	1.000	0.751	331.79	3.766	3.766	1.000	72.816
Generation	F_2 generation														
Trait	Number of flowers per plant					Individual flower weight (g)					100-flowers weight (g)				
Parameter	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA	Mean	PCV	GCV	h^2	GA
H_1	65.333	0.742	0.465	0.628	8.998	4.597	0.052	0.015	0.288	0.290	336.71	3.822	0.731	0.191	14.133
H_2	63.667	0.723	0.356	0.493	6.883	3.877	0.044	0.010	0.226	0.192	362.35	4.113	1.251	0.304	24.190
H_3	51.667	0.586	0.063	0.108	1.227	4.340	0.049	0.011	0.217	0.207	327.31	3.715	0.409	0.110	7.905
H_4	85.333	0.969	0.635	0.655	12.275	4.477	0.051	0.015	0.290	0.285	352.16	3.997	0.918	0.230	17.747
H_5	61.333	0.696	0.376	0.541	7.278	5.167	0.059	0.020	0.343	0.389	390.86	4.436	1.277	0.288	24.686
H_6	74.667	0.847	0.598	0.706	11.569	4.547	0.052	0.015	0.294	0.294	325.65	3.696	0.533	0.144	10.311
H_7	63.667	0.723	0.408	0.565	7.894	4.803	0.055	0.018	0.337	0.355	376.39	4.272	1.299	0.304	25.121
H_8	45.667	0.518	0.034	0.066	0.658	4.393	0.050	0.014	0.282	0.272	335.06	3.803	0.710	0.187	13.726
H_9	46.333	0.526	0.143	0.272	2.765	4.783	0.054	0.017	0.315	0.330	372.52	4.228	1.253	0.296	24.220
H_{10}	53.667	0.609	0.216	0.354	4.173	3.617	0.041	0.007	0.178	0.141	348.49	3.955	1.173	0.297	22.682

GS - Growth stage, DAT - Days after transplanting, PCV - Phenotypic coefficient of variation, GCV - Genotypic coefficient of variation, h^2 - Heritability, GA - Genetic advance

The maximum values were recorded in H_5 (371.120 g and 390.860 g in F_1 and F_2 generation, respectively). The above-mentioned outcomes elucidate that these traits are stable and amenable to direct selection, especially in H_5 and H_2. Similar trend for the trait was observed in China aster (20), French marigold (1) and African marigold (21).

Yield traits

The recorded and analysed yield data are presented in Table 6 and discussed below.

Yield per plant (g)

In F_1, yield ranged from 310.88 g (H_6) to 371.12 g (H_5). Heritability = 1.000; GA peaked at 81.448 (H_5). Whereas in F_2 yield ranged from 193.85 g (H_{10}) to 338.91 g (H_6). In the F_1 generation, H_6 recorded the highest GA (58.266 g), whereas in F_2, H_4 showed the highest GA (67.668), with high heritability.

Yield per hectare (t)

In F_1, yield per hectare ranged from 13.53 t (H_1) to 17.22 t (H_3). GCV was modest (0.154-0.195), but heritability was equal to unity. While in F_2 generation, hybrids yielded up to 18.900 t/ha (H_4) with maximum GA (1.789) and values were consistent in H_4 and H_5. These findings express that yield traits exhibit both additive and non-additive control, requiring selection and hybridisation for improvement. H_4,

Table 6. Genetic analysis of China aster hybrids for yield traits in early generations

Generation	F_1 generation									
Trait	Yield per plant (g)					Yield per hectare (t)				
Parameter	Mean	PCV	GCV	Heritability	GA	Mean	PCV	GCV	Heritability	GA
H_1	171.110	1.942	1.942	1.000	37.553	13.530	0.154	0.154	1.000	2.969
H_2	205.010	2.327	2.327	1.000	44.993	16.360	0.186	0.186	1.000	3.590
H_3	216.210	2.454	2.454	1.000	47.451	17.220	0.195	0.195	1.000	3.779
H_4	212.010	2.406	2.406	1.000	46.529	16.950	0.192	0.192	1.000	3.720
H_5	208.000	2.361	2.361	1.000	45.649	16.650	0.189	0.189	1.000	3.654
H_6	175.830	1.996	1.996	1.000	38.589	14.470	0.164	0.164	1.000	3.176
H_7	195.750	2.222	2.222	1.000	42.960	14.930	0.169	0.169	1.000	3.277
H_8	179.990	2.043	2.043	1.000	39.501	14.360	0.163	0.163	1.000	3.152
H_9	185.760	2.108	2.108	1.000	40.768	13.780	0.156	0.156	1.000	3.024
H_{10}	198.010	2.247	2.247	1.000	43.456	15.750	0.179	0.179	1.000	3.457
Generation	F_2 generation									
Trait	Yield per plant (g)					Yield per hectare (t)				
Parameter	Mean	PCV	GCV	Heritability	GA	Mean	PCV	GCV	Heritability	GA
H_1	300.413	3.410	2.471	0.725	47.787	14.834	0.168	0.029	0.175	0.569
H_2	245.923	2.791	1.549	0.555	29.949	12.144	0.259	0.075	0.291	1.062
H_3	223.887	2.541	0.941	0.370	18.186	11.656	0.283	0.058	0.207	0.772
H_4	382.740	4.344	3.500	0.806	67.668	18.900	0.215	0.093	0.431	1.789
H_5	316.867	3.596	2.451	0.681	47.384	15.447	0.233	0.059	0.253	0.991
H_6	338.913	3.847	3.013	0.783	58.266	16.736	0.190	0.062	0.327	1.203
H_7	306.487	3.479	2.534	0.728	48.996	15.134	0.172	0.040	0.232	0.770
H_8	199.563	2.265	0.912	0.402	17.625	10.454	0.248	0.059	0.237	0.788
H_9	221.450	2.513	1.190	0.474	23.013	11.335	0.238	0.059	0.250	0.846
H_{10}	193.853	2.200	0.825	0.375	15.956	10.575	0.252	0.074	0.294	0.990

GS - Growth stage, DAT - Days after transplanting, PCV - Phenotypic coefficient of variation, GCV - Genotypic coefficient of variation, h^2 - Heritability, GA - Genetic advance

H_5 and H_6 are particularly promising hybrids. Research indicates that similar outcomes for quantitative yield traits in Asteraceae crops such as China aster (17), chrysanthemum (22, 23), French marigold (24) and African marigold (21).

Conclusion

Based on the study's findings, the following significant conclusions were drawn. High heritability (close to 1) across traits indicates minimal environmental influence and strong genetic determination. GCV and GA were especially high for yield, plant height, plant spread and number of flowers, indicating their suitability for effective selection. Hybrids H_4, H_5, H_6 and H_9 consistently outperformed others across multiple traits, establishing their potential as suitable hybrids for future breeding programs.

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Authors' contributions

KDR, HBR and UC contributed to conceiving the research idea, carried out the experiment and led the manuscript preparation and editing and maintained experimental records. VKR conceived the research idea, planned in design of the breeding strategy and C contributed to hybrid development and data analysis, monitored the field trial, plant growth and yield traits. DVP collected phenotypic data, helped in statistical analysis and assisted in writing the results section. HBR contributed to genetic analysis and trait interpretation, technical writing, drafting, statistical analysis and critically reviewed the manuscript. KSAK involved in technical writing, drafting and statistical analysis, critically reviewed the manuscript for genotypic performance across generations. NCV supported in data tabulation and correlation studies of growth and yield parameters. GMK assisted in the graphical presentation of data and proofreading of the final manuscript. JMS helped in compiling references, formatting the manuscript and cross-verifying data accuracy. RS provided expert guidance on genetic parameters and contributed to statistical analysis. SH contributed during data collection, laboratory analysis, manuscript review and contributed to structuring the discussion section. All authors read and approved the final manuscript.

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During the preparation of this work, the authors used CHAT GPT (OpenAI) to correct the grammatical errors and reduce the word count. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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