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RESEARCH ARTICLE

Heterosis for morphological and biochemical traits in cauliflower (*Brassica oleracea* L. var. *botrytis*) under mid hill zone of North Western Himalayas

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Abstract

Heterosis breeding is a quick and convenient way of combining desirable characters, which has assumed greater significance in the production of hybrids. Enough information is available regarding heterosis for components related to yield. However, we are lacking information regarding the heterotic behavior of biochemical traits in cauliflower. Therefore, the present study was undertaken to elicit information about the extent of heterosis for morphological and biochemical traits in cauliflower by hybridizing four diverse parents during *rabi* 2013-2014 and 2014-2015. Six cross-combinations, along with parents and standard checks, were evaluated in randomized block design during *rabi* 2015-2016. Among the hybrids, significantly highest levels of heterosis were found in DPCaY-3 × DPCaY-6, Palam Uphar × DPCaY-6 and DPCaY-8 × DPCaY-6 for earliness, marketable yield per plant and its related traits, whereas cross DPCaY-8 × DPCaY-6 for biochemical traits. Hence these hybrids offer a higher scope and can be further tested under different agro-climate for commercial production.

Keywords: Biochemical traits, Cauliflower, Curd weight, Heterosis, Standard check

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Introduction

Among cole crops, cauliflower (*Brassica oleracea* L. var. *botrytis*) is one of the most important winter vegetables grown throughout the world which are rich in different phytochemicals and bioactive compounds. In addition, cauliflower is fairly a high source of glucosinolates (40–80 mg/100 g), predominantly sinigrin and glucobrassicin, which have predominantly anti-carcinogenic properties. The curd of cauliflower is generally white in color and has been described as a pre-floral structure, which has the characteristics of both the vegetative and reproductive apices. The original introductions of cauliflower were Cornish types, which originated in England, followed by temperate types (Erfurt or Snowball type), which originated in Germany and the Netherlands in 18th century (Swarup and Chatterjee, 1972). It is likely that Cornish types have contributed most of the genes to Indian cauliflower, like long stalk, open growth habit and yellowish, uneven and strong flavored curds. Some of the leaf and curd characteristics were also contributed by 'Roscoff', 'Italian', and 'Northern' types. The present-day Indian (tropical) cauliflower is a result of intercrossing between European and Cornish types, which is more adapted and resistant to high temperature, high rainfall and the ability to produce seeds in North Indian plains. It has been recognized as a different type not only at

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the national but at the international level (Nieuwhof, 1969; Swarup and Chatterjee, 1972; Crisp, 1982).

Cauliflower is a valuable component of a healthy diet because of its high content of glucosinolates (Schonhof et al., 2004), which can be converted by plant enzymes to other compounds, such as isothiocyanates and indole-3-carbinol. These have potential anticancer properties. Cauliflower extract contains ascorbic acid, carotenoids, tocopherols, isothiocyanates, indoles, and flavonoids, which act as potential chemopreventive agents to check the initiation and promotion of carcinogenesis. Its curd extract is used as a traditional medicine in the treatment of scurvy, as a blood purifier, and as an antacid. Its seeds also have contraceptive properties (El-Dean, 1972). Cauliflower occupies a proud place in India due to its delicious taste and flavor and being nutritive as it contains vitamin C (48.2 mg), potassium (299 mg), magnesium (15 mg) and other nutrients. It is grown for its white tender curd commonly used as a vegetable, in curry and soup. It is also used in the form of pickles and pakoras in the Indian sub-continent, whereas in other countries it is also used by making nuggets and using its flour in pizza and muffins. The edible portion of this vegetable is approximately 45% of the plant (Rai and Yadav, 2005). Ranging from temperate to tropics, it is cultivated worldwide in different climatic conditions and is available around the year in the market. Across the globe, it is cultivated in an area of 14,17,806 ha with a production of 2,65,04,006 metric tonnes and productivity of 18.69 metric tonnes/ha (Anonymous, 2018). In India, cauliflower is cultivated in an area of 4,59,000 ha with a production of 88,00,000 metric tonnes and its productivity is 19.2 metric tonnes/ha (Anonymous, 2018). In Himachal Pradesh, it is being cultivated in an area of 5,310 ha with a production of 1,24,330 metric tonnes and productivity of 23.41 metric tonnes/ha (Anonymous, 2017). In the state, it is grown commercially as an off-season crop during the summer-rainy (March to November) season in Shimla, Mandi, Solan, Kullu, Lahaul & Spiti and Kangra districts, bringing lucrative returns to the farmers. The development of quality F_1 hybrids with better productivity and adaptability is the main focus of vegetable breeding throughout the world. The F_1 hybrids of cauliflower are increasingly becoming popular for their uniformity, wider adaptability and round-the-year availability (Sharma et al., 2004; Singh et al., 2018). In the case of cauliflower, along with yield, special emphasis is also required towards the improvement of its quality characteristics, including nutritiveness and insect-pest and disease resistance. In light of the above-stated facts, there is an urgent need to evolve stable high yielding varieties/hybrids possessing desirable biochemical traits. Therefore, the present investigation was carried out with the objective to study the extent of heterosis and to identify the heterotic combinations possessing desirable morphological and biochemical traits.

Materials and Methods

Experiment Location

The investigation was carried out at the Experimental Farm of the Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during *rabi* seasons of 2013-14 to 2015-16 (32° 6′ N latitude, 76° 3′ E longitude and at an elevation of 1290.8 m above mean sea level). Agro-climatically, the research location represents the mid-hill zone of the North Western Himalayas and is characterized by a humid sub-temperate climate with high rainfall (2500 mm). The mean weekly meteorological data during the crop growing period of location is given in Fig 1. The soil consists of a silty clay loam texture with an acidic nature.

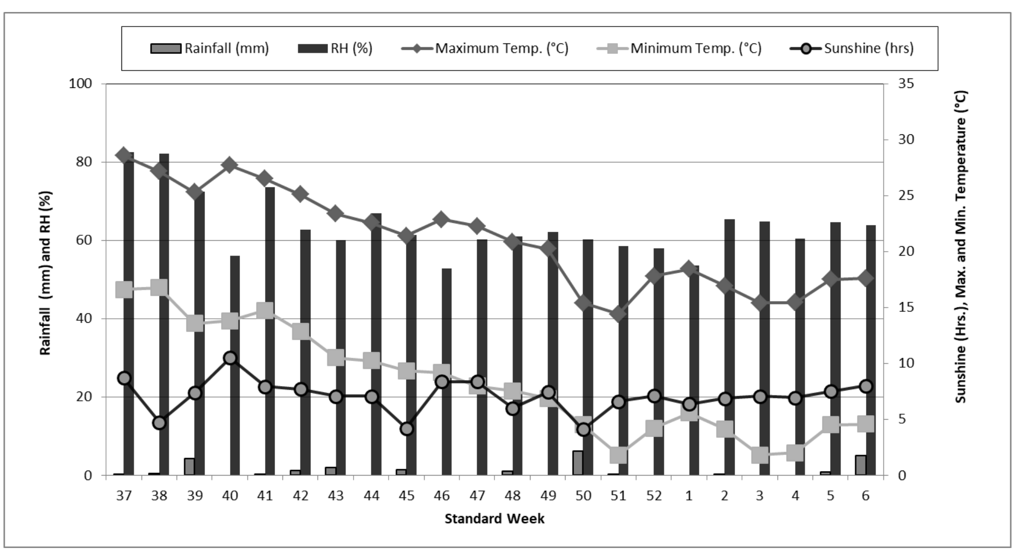

Figure 1: Mean weekly meteorological data during the evaluation period (September 11, 2015 to February 11, 2016) at Palampur

Breeding Materials and Experimental Design

The present investigation was carried out at the Experimental Farm of the Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, HP. The site of the experiment is located at 32°60 N latitude, 76°30 E longitude and 1290.8 m altitude. Agro-climatically, the location represents the mid-hill zone of Himachal Pradesh (zone-II) and is characterized by humid sub temperate climate with high rainfall (2500mm) of which 80% is received from June to September. To study the extent of heterosis in various morphological and biochemical traits, four diverse genotypes of cauliflower developed by the Department of Vegetable Science and Floriculture, CSKHPKV Palampur, namely, DPCaY-3, Palam Uphar, DPCaY-8 and DPCaY-6 were involved in a crossing program to generate the experimental material. Cauliflower hybrid no. 626 developed by Sungro Seeds Private Limited, was used as a standard check. All the parents were crossed with each other in diallel mating design (excluding reciprocals) by using the recommended procedure of hand emasculation and bud pollination to develop the F_1 hybrids *viz*., DPCaY-3 × Palam Uphar, DPCaY-3 × DPCaY-8, DPCaY-3 × DPCaY-6, Palam Uphar × DPCaY-8, Palam Uphar × DPCaY-6 and DPCaY-8 × DPCaY-6. Four parents and six hybrid combinations, along with standard check, were evaluated in Randomized Block Design (RBD) with three replications during *rabi*, 2015-2016. Seeds were sown in nursery beds of size 3 × 1 × 0.15 m and seedlings were transplanted in the field at an inter and intra-row spacing of 60 × 45 cm. Besides the application of Farm Yard Manure @ 20 tonnes/ha, chemical fertilizers were applied as per the recommended package of practices (150 kg N, 100 kg P_2O_5, 50 kg K_2O/ha). All the intercultural operations were carried out in accordance with the recommended schedule.

Observations

Observations were recorded on ten competitive plants in each entry and replication for the morphological and biochemical traits *viz*., days to curd initiation, days to marketable curd maturity, plant frame (cm), plant height (cm), gross curd weight (g), marketable yield per plant (g), net curd weight (g), curd depth (cm), curd diameter (cm), curd size index (cm^2), curd compactness (degree), leaf size index (cm^2), percent marketable curds (%), harvest index (%), dry matter content (%), total soluble solids (°Brix), vitamin C (mg/100g), total sugars (%) and total phenols (mg/g).

Statistical Analysis

Heterosis was worked out over better parent and standard check Hybrid 626. The data were analyzed using the software Statistical Package for Agricultural Research (SPAR-2.0) developed by Indian Agricultural Statistics Research Institute, New Delhi. Significance was tested through F test at 5 and 1% probability.

Table 1a: Heterosis over better parent and standard check (Hybrid 626) for different morphological and biochemical traits in cauliflower

S. No.	*Crosses & Traits*	*Days to curd initiation*		*Days to marketable curd maturity*		*Plant frame (cm)*		*Plant height (cm)*		*Gross curd weight (g)*		*Marketable yield per plant (g)*	
		Percent increase/ decrease over		*Percent increase/ decrease over*		*Percent increase/ decrease over*		*Percent increase/ decrease over*		*Percent increase/ decrease over*		*Percent increase/ decrease over*	
		BP	*SC*	*BP*	*SC*	*BP*	*SC*	*BP*	*SC*	*BP*	*SC*	*BP*	*SC*
1	DPCaY-3 × PU	-3.66 *	-7.06 *	-4.65 *	-7.87 *	1.83	1.93 *	-3.18	1.29	5.51*	6.52*	10.69 *	9.96*
2	DPCaY-3 × DPCaY-8	-3.70 *	-8.24 *	-5.45 *	-8.99 *	1.67	0.83	-5.31 *	-5.73*	6.81*	11.53*	9.48 *	16.37*
3	DPCaY-3 × DPCaY-6	-10.56 *	-15.29 *	-7.54 *	-12.73 *	5.51 *	5.61 *	-4.76 *	-0.37	7.58*	15.25*	11.74 *	26.33*
4	PU × DPCaY-8	-3.09	-7.65 *	-4.67 *	-8.24 *	4.26 *	3.40 *	-5.43 *	-5.85*	5.61*	10.28*	10.03 *	16.96*
5	PU × DPCaY-6	-4.97 *	-10.00 *	-4.37 *	-9.74 *	-3.69 *	0.55	-4.90 *	3.16	8.71*	16.45*	9.59 *	23.89*
6	DPCaY-8 × DPCaY-6	-5.59 *	-10.59 *	-2.78 *	-8.24 *	1.74	0.90	-3.96	-4.38*	8.05*	15.75*	9.13 *	23.38*

*Significant at $p \leq 0.05$

Table 1b: Heterosis over better parent and standard check (Hybrid 626) for different morphological and biochemical traits in cauliflower

S. No.	Crosses & Traits	*Net curd weight (g)*		*Curd depth (cm)*		*Curd diameter (cm)*		*Curd size index (cm²)*		*Curd compactness (degree)*		*Leaf size index (cm²)*	
		Percent increase/ decrease over		*Percent increase/ decrease over*		*Percent increase/ decrease over*		*Percent increase/ decrease over*		*Percent increase/ decrease over*		*Percent increase/ decrease over*	
		BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
1	DPCaY-3 × PU	12.89 *	12.93*	6.24 *	4.91 *	7.44 *	10.91 *	15.94 *	15.10 *	1.38	1.09	-21.94*	-0.45
2	DPCaY-3 × DPCaY-8	11.76 *	20.04*	7.50 *	-0.80	2.26	7.15 *	7.70 *	8.76 *	4.19 *	1.81	-25.02*	-13.62*
3	DPCaY-3 × DPCaY-6	14.68 *	32.15*	6.44 *	7.68 *	4.24 *	15.66 *	20.53 *	33.52 *	1.42	3.26*	-17.57*	11.29*
4	PU × DPCaY-8	12.25 *	20.57*	10.26 *	8.88 *	3.31	8.25 *	10.58 *	11.67 *	1.14	0.85	-31.82*	-13.04*
5	PU × DPCaY-6	12.16 *	29.26*	6.53 *	7.76 *	3.24	14.56 *	16.66 *	29.24 *	2.13	3.98*	-15.65*	13.89*
6	DPCaY-8 × DPCaY-6	11.33 *	28.29*	6.44 *	7.68 *	3.22	14.54 *	18.27 *	31.02 *	0.71	2.53	-36.01*	-13.60*

*Significant at $p \leq 0.05$

Table 1c: Heterosis over better parent and standard check (Hybrid 626) for different morphological and biochemical traits in cauliflower

S. No.	Crosses & Traits	*Percent marketable curds (%)*		*Harvest index (%)*		*Dry matter content (%)*		*Total soluble solids (°Brix)*		*Vitamin C (mg/100g)*		*Total sugars (%)*		*Total phenols (mg/g)*	
		Percent increase/ decrease over		*Percent increase/ decrease over*		*Percent increase/ decrease over*		*Percent increase/ decrease over*		*Percent increase/ decrease over*		*Percent increase/ decrease over*		*Percent increase/ decrease over*	
		BP	*SC*	*BP*	*SC*	*BP*	*SC*	*BP*	*SC*	*BP*	*SC*	*BP*	*SC*	*BP*	*SC*
1	DPCaY-3 × PU	5.88	4.21	3.51 *	3.21 *	6.25 *	13.11 *	11.76 *	7.55	-14.92 *	-3.74	11.39 *	14.08 *	-4.25 *	-8.62 *
2	DPCaY-3 × DPCaY-8	9.95 *	10.53*	2.49 *	4.32 *	0.00	6.46 *	1.85	3.77	-2.46	59.45 *	5.38 *	-42.20 *	-3.56 *	17.56 *
3	DPCaY-3 × DPCaY-6	6.32	6.32	3.87 *	9.62 *	-11.79 *	-6.09	4.00	-1.89	-6.89 *	59.28 *	9.55 *	-35.23 *	-1.24	22.66 *
4	PU × DPCaY-8	5.24	5.79	4.17 *	6.03 *	-19.33 *	-14.24 *	1.85	3.77	-8.66 *	49.30 *	8.45 *	-40.52 *	-14.27 *	4.50 *
5	PU × DPCaY-6	7.37	7.37	0.81	6.39 *	-1.49	-13.15 *	1.96	-1.89	-6.86 *	59.34 *	14.07 *	-32.57 *	-10.07 *	11.70 *
6	DPCaY-8 × DPCaY-6	5.76	6.32	1.00	6.59 *	1.27	7.66 *	5.56	7.55	9.02 *	86.50 *	-7.68 *	-49.37 *	7.36 *	33.35 *

*Significant at $p \leq 0.05$

Results and Discussion

The results obtained after evaluating the six hybrids developed through the hybridization of four diverse parents are presented in Table 1a-c and discussed. Heterosis in the negative direction is desirable for days to curd initiation. In this trait, it varied from -10.56 to -3.09% over better parent and -15.29 to -7.06% over standard check. All the crosses except PU × DPCaY-8 showed significant negative heterosis over better parents, while over standard check, all the crosses exhibited significant and negative heterosis. These results corroborate the findings of Varalakshmi (2009) and Mehra (2012).

For days to marketable curd maturity, the interest of the breeder lies in search of combinations having negative heterosis because they result in early and better returns to the farmers. All the crosses displayed significant negative heterosis over better parents as well as standard checks for this trait. Heterosis with variable magnitude has also been observed earlier by Jindal and Thakur (2003), Garg and Lal (2005), Singh et al. (2009) over better parent and Varalakshmi (2009) over better parent and standard check. The magnitude of heterosis for the plant frame varied from -3.69 to 5.51% over better parent and from 0.55 to 5.61% over the standard check. Only one cross (PU × DPCaY-6) exhibited desirable significant negative heterosis over a better parent. The earlier researchers, namely Garg and Lal (2005) and Singh et al. (2009) have also observed heterosis for plant spread. A shorter plant height is desirable. Out of six, four cross-combinations exhibited desirable significant negative heterosis over a better parent, whereas three crosses showed significant negative heterosis over the standard check. These findings are in broad conformity to the findings of Jindal and Thakur (2003), Garg and Lal (2005), Kumari (2014), and Verma and Kalia (2015).

Gross curd weight in general, directly reflects the yield potential of the plant. Yield is the main criterion in any breeding program. From an economic view point, it is the marketable yield that is of relevance to the farmers. A given genotype may give a higher gross yield but it is not necessary that the marketable yield per plant will also be higher. All of the crosses were able to display heterosis in a desirable direction over better parent and standard checks for gross curd weight and marketable yield. Similar observations were reported by Thakur et al. (2001) and Verma and Kalia (2015) in their respective studies. Moreover, net curd weight is an important trait which decides the commercial viability of the genotype. The range of heterosis for this trait varied from 11.33 to 14.68% over better parents and 12.93 to 32.15% over the standard check. All the crosses exhibited significant heterobeltiosis as well as standard heterosis for this trait. Hybrid vigor for net curd weight has been reported quite often in literature (Garg and Lal, 2005; Varalakshmi, 2009; Verma and Kalia, 2015).

Heterosis over better parent for curd depth ranged from 6.24 to 10.26%, whereas heterosis over standard check varied from -0.80 to 8.88%. All the crosses showed desirable significant positive heterobeltiosis, whereas except one all the crosses displayed significant positive standard heterosis for this character. These results are in agreement with the findings of Jindal and Thakur (2003). The magnitude of heterosis for curd diameter varied from 2.26 to 7.44% over better parent and from 7.15 to 15.66% over standard check. Only two crosses displayed significant positive heterobeltiosis, whereas all crosses displayed significant positive standard heterosis for this trait. The results are in line with those of Jindal and Thakur (2003), Garg and Lal (2005) and Singh et al. (2009). The yield being a complex character, improvement is easier if progress is made through its attributing characters like the curd size index. All the crosses were able to display significant positive heterosis over better parent and standard check for curd size index. Similar observations have also been reported by Garg and Lal (2005) and Varalakshmi (2009).

The compactness of curd in cauliflower is a very desirable quality trait from the consumer as well as the breeder's point of view. Visual observations can judge the compactness and feel of the hand, but in such cases the bias factor with different individuals cannot be avoided. So, to give the metric treatment to this trait, the angles formed between the main axis and extreme ends of the curd were measured. Only one cross (DPCaY-3 × DPCaY-8) exhibited positive significant heterobeltiosis, whereas two crosses (DPCaY-3 × DPCaY-6 and PU × DPCaY-6) showed positive significant standard heterosis for this trait. Thakur et al. (2004) and Garg and Lal (2005) have also reported hybrid vigor for curd compactness with variable magnitude in a good number of cross combinations. The variation for heterosis in different studies may be attributed to the differences in the genotypes involved in the cross combinations and growing conditions. However, the leaf size index is also one of the most important yield-contributing traits. None of the crosses displayed desired significant positive heterosis over a better parent. Two crosses *viz*., DPCaY-3 × DPCaY-6 and PU × DPCaY-6 showed desirable significant positive heterosis over the standard check. Verma and Kalia (2015) also reported positive heterosis over a standard check for leaf area in their respective study.

Heterosis for percent marketable curds ranged from 5.24 to 9.95% over a better parent, whereas heterosis over standard check ranged from 4.21 to 10.53%. Only one cross exhibited significant positive heterosis over better parent as well as over standard check for percent marketable curds. These results are in agreement with the findings of Garg and Lal (2005) and Kumari (2014). For harvest index, four crosses (DPCaY-3 × PU, DPCaY-3 × DPCaY-8, DPCaY-3 × DPCaY-6 and PU × DPCaY-8) over better parent and all cross-over standard check displayed significant desirable positive heterosis. Heterosis for this trait has also been reported by Jindal and Thakur (2003), Mehra (2012) and Verma and Kalia (2015) in different sets of material and environmental conditions. Dry matter content in cauliflower is a desirable quality character. Only one cross (DPCaY-3 × PU) exhibited significant positive heterobeltiosis, whereas three crosses (DPCaY-3 × PU, DPCaY-3 × DPCaY-8 and DPCaY-8 × DPCaY-6) exhibited significant positive standard heterosis for this trait. Upadhyaya and Kumar (1983) also reported heterosis for dry matter content in cauliflower. For total soluble solids, only one cross showed significant positive heterosis over a better parent, whereas none of the crosses showed significant positive heterosis over the standard check. Kumari (2014) has reported positive heterosis for total soluble solids.

The development of cauliflower F_1 hybrids with higher ascorbic acid content will eventually help in preventing scurvy disease through dietary intake. Emerging research results indicate that ascorbic acid, existing widely in plants as a micromolecule substance, fulfills its essential roles in a series of physiological processes such as plant defense against oxidization, plant cell division, cell expansion, growth and development. A range of heterosis varied from -14.92 to 9.02% over better parents. In the case of a standard check, heterosis ranged from -3.74 to 86.50%. Positive and significant desired heterosis was observed in the cross DPCaY-8 × DPCaY-6 over the better parent, whereas all crosses except DPCaY-3 × PU displayed significant positive heterosis over the standard check. Jindal and Thakur (2003), Dey et al. (2014) and Kumari (2014) have also noticed cross combinations with positive heterosis for this trait. In the present study, only one cross (DPCaY-8 × DPCaY-6) showed desired significant negative heterosis over a better parent, while except one (DPCaY-3 × PU) all the crosses showed significant negative standard heterosis for total sugars. For total phenols, the magnitude of heterobeltiosis and standard heterosis varied from -14.27 to 7.36% and -8.62 to 33.35%, respectively. Significant positive (desirable) heterosis over better parent displayed by only one cross, i.e., DPCaY-8 × DPCaY-6. All the crosses except one (DPCaY-3 × PU) displayed significant positive standard heterosis.

Heterosis studies provide information about the percent increase or decrease of F_1 over better parent and standard variety and, thus, help in spotting out the best crosses for yield and quality traits but, do not indicate the possible causes of superiority of crosses. DPCaY-3 × DPCaY-6, Palam Uphar × DPCaY-6 and DPCaY-8 × DPCaY-6 showed significant and positive heterosis over better parent and standard check for earliness, marketable yield per plant and its related traits, while crossing DPCaY-8 × DPCaY-6 also showed significant and positive heterosis over better parent and standard check for biochemical traits and these cross-combinations got top ranking among all the crosses.

Conclusion

The extent of heterosis revealed that the hybrids *viz.,* DPCaY-3 × DPCaY-6, Palam Uphar × DPCaY-6 and DPCaY-8 × DPCaY-6 showed the highest desirable heterosis over better parent and standard check for earliness, marketable yield per plant and its related traits, while cross DPCaY-8 × DPCaY-6 also showed significant and positive heterosis over better parent and standard check for biochemical traits. Hence these hybrids having high heterosis for a maximum number of desirable traits can be further tested for yield and related traits under different agro-climates for commercial exploitation.

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सारांश

संकर ओज (हेटेरोसिस) प्रजनन वांछनीय लक्षणों के संयोजन का एक त्वरित और सुविधाजनक तरीका है जिसने संकरों के उत्पादन में अधिक महत्व प्राप्त कर लिया है। उपज से संबंधित घटकों के लिए संकर ओज के संबंध में पर्याप्त जानकारी उपलब्ध है। हालाँकि, हमारे पास फूलगोभी में जैव रासायनिक लक्षणों के विषम व्यवहार के बारे में जानकारी का अभाव है। इसलिए, यह अध्ययन रबी 2013-2014 और 2014-2015 के दौरान चार विविध वंशक्रमो को संकरण करके फूलगोभी में रूपात्मक और जैव रासायनिक लक्षणों के लिए संकर ओज की सीमा के बारे में जानकारी प्राप्त करने के लिए किया गया था। रबी 2015-2016 के दौरान याद्दच्छिक ब्लॉक डिजाइन में वंशक्रमो और मानक प्रजाति के साथ छह संकर संयोजनों का मूल्यांकन किया गया था। संकरों में, क्व्बंल्-3 × क्व्बंल्-6, पालम उपहार × क्व्बंल्-6 और क्व्बंल्-8 × क्व्बंल्-6 में शीघ्रता, प्रति पौधा विपणन योग्य उपज और इसके संबंधित लक्षणों के लिए संकर ओज का उच्चतम स्तर पाया गया, जबकि जैव रासायनिक लक्षणों के लिए संकर क्व्बंल्-8 × क्व्बंल्-6 का उच्चतम स्तर पाया गया हैं । इसलिए ये संकर उच्च गुंजाइश प्रदान करते हैं और व्यावसायिक उत्पादन के लिए विभिन्न कृषि-जलवायु के तहत आगे परीक्षण किया जा सकता है।