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RADIATION-INDUCED VARIATION IN RAY-FLORET CHARACTERISTICS OF ANNUAL CHRYSANTHEMUM

R. S. RANA
Botany Division, Indian Agricultural Research Institute, New Delhi

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ABSTRACT

Successfull application of X-irradiation to obtain viable mutants affecting ray-floret characteristics of annual chrysanthemum is reported. Either strap-shaped flat rays of the control type had strikingly changed in their appearance or were entirely lacking. An interesting mutation resulted in transformation of pistillate nature of the ray florets into bisexual type. The occurrence of mutant phenotypes is genetically accounted for and the usefulness of experimental production of mutations in plant breeding is discussed.

INTRODUCTION

Much work in the sphere of mutation breeding has so far been done on crop plants in view of their greater economic significance. There is however by now sufficient evidence to show that possibilities of inducing successful mutations are better with some types of plants than with others. It is now recognised, for example, that induced mutations offer as good if not a better scope in the improvement of ornamental plants since as for ornamentals "something different" is often synonymous to "something better".

These materials mostly need improving; qualitative characters such as flower form and colour are often determinated in a simple way. With this in mind, a mutation breeding programme on some popular ornamental plants was undertaken and the investigation in annual chrysanthemum forms part of this project.

MATERIAL AND METHODS

Chrysanthemum carinatum (Syn. *tricolour*) SCHOUSB., which is the most common of the numerous annual chrysanthemums, is distinguished from other species of this group by the keeled (carinated) involucral bracts and bears solitary flower-heads with white or yellow ray-florets and often a dark pigmented ring at the base of "petals". The two colours together with the dark purple disc florets account for the name "tricolour". Its diploid chromosome number is 18, the species is self-incompatible and belongs to the family Compositae. A popular variety, procured from Chelsea Physic Garden (England), is the subject of this study.

Dry seeds were subjected to an acute X-ray dose of 15 Kr at an operating voltage of 50 Kv and sown immediately after the treatment. Allowing for the highly heterozygous nature of the experimental material because of its self-incompatibility system, a large control population was raised each year for a critical comparison.

Experimental results

1. *Mutant types*

The X_2 population, raised from seeds of the open-pollinated X_1 parents, consisted of 315 progenies comprising a total of 9,450 plants. The most striking variation in these plants was observed in respect of ray floret characteristics of their flower-heads. In control type ray florets, the corolla is conspicuous and strap-shaped, being enlarged on one side of the floret (Fig. 1). Four distinct mutant types altering normal appearance of the ray florets could be easily recognised (Figs. 2 to 7): one of these had dissected type rays in which the strap-shaped petals were split into two along their entire length (Fig. 2), the second was of the tubular type in which the flat rays assumed a tubular appearance (Fig. 6), the third ("nanny" type) was characterised by very short rays whose size never exceeded one-fourth of the normal size (Fig. 3) while the fourth was the apetalous type in which the ray florets were lacking (Fig. 4). In addition to these mutants transforming the appearance of the flower-heads, there appeared a mutant type in which the pistillate ray florets (Fig. 8) assumed the bisexual characteristic of the disc florets (Fig. 9).

Fertility of all the five mutant types was normal and their breeding behaviour in subsequent generations showed that all were phenotypically stable with the exception of the tubular type. Expression of the tubular effect was found to be influenced by both environmental conditions and varying genetic background.

2. *Genetic analysis*

With a view to determining genetic nature of the induced phenotypes, all the mu-

Table 1. Showing recombination analysis of crosses involving induced mutants and the control type

Cross combination	F_1 phenotype	F_2 segregation: Phenotype	Frequency: Observed	Frequency: Expected on 3:1 basis	Probability (X^2 test)
1. Normal × Dissected	Normal	Normal	65	61.50	0.30–0.50
		Dissected	17	20.50	
2. Normal × Tubular	Normal	Normal	74	69.00	0.20–0.30
		Tubular	18	23.00	
3. Normal × Nanny	Normal	Normal	67	70.50	0.30–0.50
		Nanny	27	23.50	
4. Normal × Apetalous	Normal	Normal	81	79.50	0.70–0.90
		Apetalous	25	26.50	
5. Pistillate rays × Bisexual rays	Pistillate rays	Pistillate rays	72	68.25	0.30–0.50
		Bisexual rays	19	22.75	

TABLE 2. SHOWING RECOMBINATION ANALYSIS OF CROSSES AMONG THE MUTANT TYPES

Cross combination	F_1 phenotype	F_2 segregation: Phenotype	Frequency: Observed	Frequency: Expected on 3:1 basis	Probability (X^2 test)
1. Dissected × Tubular	Dissected	Dissected	67	63.00	0.30–0.50
		Tubular	17	21.00	
2. Nanny × Dissected	Dissected	Dissected	61	63.75	0.30–0.50
		Nanny	24	21.25	
3. Dissected × Apetalous	Dissected	Dissected	59	60.75	0.50–0.70
		Apetalous	22	20.25	
4. Nanny × Tubular	Tubular	Tubular	90	85.50	0.30–0.50
		Nanny	24	28.50	
5. Tubular × Apetalous	Tubular	Tubular	73	76.50	0.30–0.50
		Apetalous	29	25.50	
6. Nanny × Apetalous	Nanny	Nanny	72	69.75	0.50–0.70
		Apetalous	21	23.25	

tant forms were crossed with the normal type and were also intercrossed among themselves. Data obtained from these crosses have been presented in Tables 1 and 2.

It is clear from these data that the four mutants affecting appearance of the ray florets differ from the normal type as well as from one another with respect to a single locus and all of them are recessively inherited compared with the control phenotype. The fact that it was not possible to recover the normal type through intercrossing of the various mutants also suggests that all these four induced types are alternative forms of a single gene governing the ray floret development and appearence. Among the mutants, the dissected type is dominant over the other three, the tubular type is dominant over the nanny and the apetalous types, while the apetalous type serves as the bottom recessives.

The recombination analysis also shows that the induced bisexual characteristic of ray florets is determined by a single gene and is recessive to the pistillate nature. There was no linkage between the two mutant loci as indicated by the relative frequencies of recombinants having dissected, tubular or nanny appearance but showing the bisexual character in segregating progenies of the intercrosses among the mutant types.

DISCUSSION

More than three decades of applied mutation work has now established beyond doubt that mutation breeding will constitute an excellent supplement to the conventional methods in practice. Excellent reviews summarising the role of radiations in the production of useful mutations and potentialities of mutation breeding are now available (GAUL, 1958; GUSTAFSSON and WETTSTEIN, 1948; SMITH, 1958; STUBBE, 1958; SPARROW and KONZAK, 1958; PRAKKEN, 1959; MACKEY, 1961). It is recognized that special opportunities for improvement through mutation breeding exist in ornamental plants since the high degree of heterozygosity common in these plants renders the production of a progeny with the desirable parental qualities through recombination breeding less possible. It seems possible that specific improvements in these plants may be brought about more readily by mutagenic treatment than by conventional methods. Reference may be made here to the investigations of JANK (1957) who showed in *Chrysanthemum indicum* that it is possible to obtain a wide spectrum of flower colours be means of induced mutations, the genotype remaining otherwise unchanged.

In view of the established fact that bud sports were largely responsible for the evolution of new varieties in ornamental plants, experimental induction of similar changes obviously presents great opportunities. As far as the somatic mutations are concerned, a number of induced flower colour changes by irradiating the growing tip were reported in many ornamental plants (SINGLETON *et al*, 1956; SAGAWA and MEHLQUIST, 1957, 1959). The induced changes, however, appear as chimeras and it is not always possible to isolate them for the purpose of developing new strains. The problems of technique relate primarily to the detection and propagation of single event mutations that have to compete with non-mutated cells in the multicellular meristem in order to be recognized. Research is required for ways to promote a favourable shift in intercellular selection within the meristem. SWAMINATHAN (1958) suggested the removal of buds from regions of chimeral composition and grafting them on to suitable stocks or repeatedly cutting back the irradiated shoots to enable the growth of mutated cells in the chimeral tissue.

By means of X-irradiation of seeds, JAIN and his associates at the Indian Agricultural Research Institute were able to induce several useful mutations in *Chrysanthemum* (JAIN *et al*, 1961) and *Cosmos* (RANA *et al*, 1963). Tubular and double type of flowers are particularly attractive and have distinct ornamental appeal. A tubular or a double type strain, if released for commercial production, can be expected to be much in demand since *Chrysanthemum* is a hardy winter annual, adaptable to a wide range of environmental conditions. Another possibility is to combine the two characters, namely, the doubleness and the tubular condition by hybridization and evolve a double-tubular variety.

An interesting mutation observed during the present study is the single type flowers having bisexual ray florets instead of the usual pistillate rays. This character, when introduced in the double types, can be extremely significant in ensuring a regular and abundant pollen supply among the doubles. Thus, some of the induced changes may directly form the basis for new strains while others can provide valuable variation for further improvement work. It may be emphasized that, whenever possible, mutation experiments should be started with the best available stocks. The fewer the changes required to make a variety more useful and marketable, the greater seem the chances of being successful.

Apart from their breeding potentialities, the observed mutants are of fundamental interest. Different alleles of a gene, for instance, can be used to study the physiology of gene action. A series of alleles present at a locus may act by affecting one and the same reaction differently by changing the rate and (or) the quantity of the end product (GOLDSCHMIDT, 1958). If it were possible to follow the primary gene product through its various stages of interaction with other compounds leading to development of the type effect, the physiological basis for interallelic differentiation could be better understood. Certain chlorophyl allelic mutants of barley, for example, were reported to cause genetic obstacles in a chain of reactions in much the same way as that known of biochemical mutants of micro-organisms (WETTSTEIN, 1960).

Induced bisexual condition of ray florets is also of considerable interest since strap-shaped elongation of the corolla tube and development of the anthers are considered mutually exclusive in this group of plants. SAMATA (1964) has suggested that competition for certain metabolites during early ontogenic development is responsible for this effect. The present observations show that a compromise threshold ensuring normal development of both the characters is possible.

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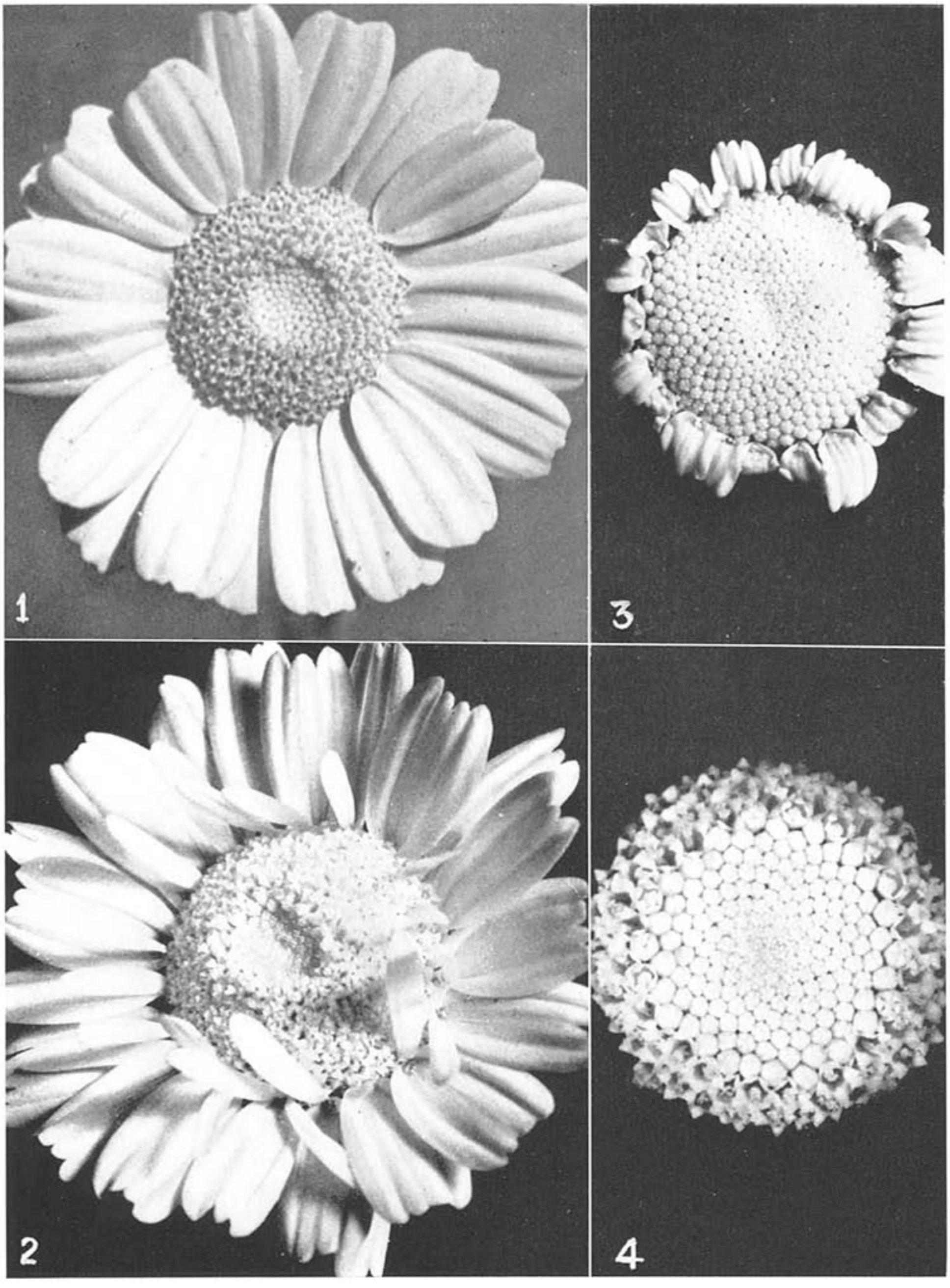

FIG. 1. Control type flower form.
FIG. 2. A mutant showing dissected type rays.
FIG. 3. A nanny type mutant with strikingly short rays.
FIG. 4. An apetalous mutant lacking the outer whorl of ray florets.

FIG. 5. A tubular mutant showing open-tipped tubular rays.
FIG. 6. A tubular type showing partial expression of the tubular character.
FIG. 7. A mutant showing complete expression of the tubular effect.
FIG. 8. A pistillate ray floret of the control type.
FIG. 9. A bisexual ray floret from a mutant.