Genetic improvement of pyrethrum

4. Selective divergence, heterosis and potential hybrid clones*

S. P. Singh and J. R. Sharma
Central Institute of Medicinal and Aromatic Plants, Lucknow-16, India

Received March 22, 1989; Accepted July 31, 1989
Communicated by G. S. Khush

Summary. Pyrethrum (Chrysanthemum cinerariefolium), an important paramedical plant is a potential source of pyrethrins, which have a long history of safe uses against mosquito larvae – a carrier of malarial parasite. It was introduced in India from Kenya in 1931. Considerable genetic diversity has been generated over the years. Repeated clonal selection could lead to isolation of a number of divergent clones representing selective divergence. Planned hybridization among some of the chosen clones could further enlarge the spectrum of variation as measured by multivariate analyses (D²-statistic and canonical analysis). The resulting hybrids manifested a variable degree of heterosis which was found to be, by and large, positively associated with the degree of divergence between the two constituent parents of a hybrid. However, the choice of the potential hybrid clone(s) for commercial exploitation was most viable when parents for hybridization were short-listed on the basis of parental divergence coupled essentially with per se performance for specific traits. The latter criterion assumes greater significance since low × low or medium × low parental hybrids also tended to register high heterosis for both the pyrethrins content and yield. Four hybrids: 234 × L, 8 × L, 326 × 395 and 319 × L were identified to be the most promising for clonal selection.

Key words: Chrysanthemum cinerariefolium – Selective divergence – Heterosis – Hybrid clones – Crop improvement

Introduction

The acute and chronic mammalian toxicity associated with synthetic insecticides/pesticides employed for controlling domestic insects pests poses severe restriction on their continuous and indiscriminate use. Development of safer toxicants, preferably natural ones, is therefore a key to a sound health care programme. Natural pyrethrins comprising two main components of flower extract – pyrethin I (including Jasmolin I, Cinerin I and pyrethin I) and pyrethrin II (including Jasmolin II, Cinerin II and pyrethrin II) (Dickinson 1987) – have a long history of safety due to their non-persistent and non-pollutant nature, also being easily biodegradable through the native enzyme system of mammals (Woodward et al. 1987; Matsumura 1975). Their potential bio-efficacy against mosquito larvae – a carrier of malarial parasite (Hobbs 1976), Varroa jacobsoni – an ectoparasitic mite of honey bees in apiculture (Nijhuis et al. 1987), Culicoides varipennis – a biting pest of man and livestock (found in alkaline/saline lake water) and a vector of bluetongue viral disease of sheep and cattle (Woodward et al. 1987), and against Mesocyclops leuckarti Sensu Lato (Cyclops) – a carrier of dranculiasis (Kamal and Mangla 1987), among others, is now well established. Moreover, natural pyrethrins are virtually non-toxic, inexpensive, and do not have a build-up of secondary resistance to pests. Therefore, unlike with ‘hard’ insecticides, no precautions need to be taken where pyrethrum-based formulations are in use. As such, they can conveniently be incorporated into integrated pest management programmes.

Pyrethrins are obtained from pyrethrum (Chrysanthemum cinerariefolium), which is self-incompatible allogamous perennial plant of the Compositae family, brought under cultivation in India in 1931 (Bhat and Pandita 1977). A great deal of genetic variability is encountered in the commercial bulk populations grown in the Kashmir valley in the north and the Palani hills in south peninsular India. Selection within such a variable population might lead to divergence from the base popu-
lation and also among selected genotypes (Hanson 1987). Hence, repeated clonal selection was exercised and a number of diverse clones were developed, as reported in earlier parts of this investigation (Singh et al. 1987, 1988a, b).

The degree of diversity so generated can be measured by three principal methods: (i) using genetic loci (genes, isozymes, restriction fraction length polymorphism, etc.) as indicated by Troyer et al. (1988) and Burr et al. (1983); (ii) by direct measurement or qualification of divergence using potent multivariate analyses, such as $D^2$ and principal component analyses or factor analysis (cf. Godshalk and Timothy 1988); and (iii) using the diversity analysis of Hanson and Moll (1986) utilising heterotic differences among single crosses, as abundant heterosis reveals genetic diversity among parents (Mungoma and Pollak 1988). We applied the latter two approaches on 12 parental clones plus 27 related half sibs in pyrethrum to achieve the following twin objectives: (a) To determine the degree of selective divergence among three pollen parents, nine seed parents (all selections) and their 27 hybrids through multivariate analyses. (b) To ascertain the degree of heterosis in a cross vis-a-vis quantified divergence between the parents involved for establishing the relationship, if any, between heterosis and genetic diversity and also for locating the best hybrid clone(s) of pyrethrum for commercial exploitation.

Materials and methods

Three pollen parents (testers) and nine selected seed parents (lines/clones) of *Chrysanthemum cinerariefolium* were crossed in line x tester fashion to generate 27 hybrids (half-sib families). Owing to the intense incompatibility reaction in each clone, selfing was not possible; even 'bud pollination' could not succeed. Conversely, cross-pollination was easy. All 39 genotypes (12 parents and 27 hybrid progenies) were transplanted through seed-nursery under standard agronomic management in randomised block design, with three replicates at the CIMAP Regional Centre, Kodaikanal (Tamil Nadu) situated at 1,650 m above sea-level. A plot comprised triple rows of 3.5 m each with 45 x 45 cm inter- and intra-hill spacings.

Metric observations were recorded three times a year on 15–20 random plants sampled from the middle row in each plot, for plant height (cm), bush diameter (cm) and flower diameter (cm) of at least 25 flowers per hill. Flowering commenced 4 months after planting and picking of flowers was carried out at 10- to 15-day intervals thereafter. Flowers were then sun dried or oven dried at 50 °C to a constant weight which represented (dried) flower yield (g/plant). Pyrethrin content (all six retrhins pooled) was estimated in dried flower powder by a modified spectrophotometer (Beckley 1950). Pyrethrin yield (mg/plant) was obtained as a product of dried flower yield and pyrethrin content (%).

Statistical analysis of data was performed for quantified/generalized ($D^2$-statistic) and spatial distances (canonical variates) as outlined in Rao (1952). Realized heterosis was computed by standard methods over the better parent (BP) as well as over the check (EP), the latter being ‘economic heterosis’.

Results and discussion

Though other plant species containing natural pyrethrins, viz. *Tagetes minuta* and *T. pitula*, occur in India, they possess low pyrethin content: 0.20%–0.65% (Kamal and Mangla 1987) as compared to >0.65% in pyrethrum. Hence, judicious exploitation of the latter assumes greater significance. Introduction and subsequent adaptation of this crop in temperate agroclimatic zones of India facilitated its successful commercial use. However, since a heterogenous material was introduced from Kenya some six decades ago (cf. Bhat and Pandita 1977), a tangible amount of genetic variation seems to have been accumulated over the years (Singh et al. 1987). Nearly absolute allogamy as a result of by self-incompatibility could further enlarge this spectrum. Vegetative multiplication coupled with seed propagation is employed to perpetuate it.

Selective divergence

From this variability, several elite clones were selected. From these, the two clones along with the local bulk were used as testers and nine as female lines to develop 27 half-sib (HS) families. The quantified degree of divergence among testers ranged from 9.9 to 68.6 ($D^2 = 35.4$); among lines from 0.6 to 41.1 ($D^2 = 12.9$) and among HS families from 2.7 to 191.9 ($D^2 = 34.7$) (Table 1). A group constellation of 39 genotypes ($D^2$ analysis) resulted in six clusters where the three testers (Sl. Nos. 1–3) fell in three separate groups, while all the lines (Sl. Nos. 4–12), except No. 11, formed a single cluster (Table 2). Hybrids formed five clusters, signifying the presence of considerable diversity among them. When all these genotypes were examined with respect to their distribution on the first two canonical axes (spatial relationship) (Fig. 1), it became apparent that they followed the group constella-

![Fig. 1. Spacial distance among parents and hybrids of pyrethrum in $Z_1$–$Z_2$ chart of principal component analysis](image-url)