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DISTANT HYBRIDIZATION: ROLE IN BRASSICA CROP IMPROVEMENT

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Abstract:

Distant hybridization has been used in the some crop plants for genetic improvement. It is very effective means of transferring desirable genes into cultivated plants from related species and genera. These hybridization is classified into two categories, i) Interspecific hybridization and ii) Intergeneric hybridization. In the *Brassica* genus, several crop species share or associated with close relationships: rapeseed (*Brassica napus*) is an ancestral hybrid between turnip (*B. rapa*) and cabbage (*B. oleracea*), and mustard species *B. juncea*, *B. carinata* and *B. nigra* share genomes in common. This type of close relationship and the profusion of wild relatives and minor crop species in the *Brassiceae* tribe which readily hybridize with the *Brassica* crop species; makes this genus an exciting instance of the use of interspecific hybridization for crop improvement.

Introduction: Hybridization between individuals from different species, belonging to the same genus or to different genera is known as distant hybridization. Individuals used for hybridization in such cases are taxonomically more distantly related than are different varieties from the same species. Distant hybridization has been used in the genetic improvement of some crop plants. It is an effective means of transferring desirable genes into cultivated plants from related species and genera. Distant hybridization is of two types, Interspecific hybridization and Intergeneric hybridization. Crossing between two different species of the same genus is referred to as interspecific hybridization. Interspecific hybridization has great value for crop breeding and agricultural production because it enriches the gene pool for plant breeding or creates new polyploid species. Interspecific hybridization is widespread in nature, where it can lead to either the production of new species or to the introgression of useful adaptive traits between species. In agricultural systems, there is also great potential to take advantage of this process for targeted crop improvement. In the *Brassica* genus, several crop species share close relationships: rapeseed (*Brassica napus*) is an ancestral hybrid between turnip (*B. rapa*) and cabbage (*B. oleracea*), and mustard species *B. juncea*, *B. carinata* and *B. nigra* share genomes in common. This close relationship and the profusion of wild relatives and minor crop species in the Brassiceae tribe which readily hybridize with the *Brassica* crop species, makes this genus an exciting instance of the use of interspecific hybridization for crop improvement.

***Brassica* crop species and their wild relatives:**

The *Brassica* genus belongs to the tribe Brassiceae (family Brassicaceae). This family comprises 338 genera and 3709 species. The members of this family are mostly herbs with annual, biennial or perennial growth habits. *Brassica* is the most prominent genus in the Brassicaceae family and includes 39 species. Many of the species in this genus are cultivated for their edible roots, leaves, stems, buds, flowers, mustard and oilseeds. For 33 of the species the chromosome number has been determined, and ranges from $n = 7$ up to $n = 20$. The diploid species *B. rapa* (AA, $n = 10$), *B. nigra* (BB, $n = 8$) and *B. oleracea* (CC, $n = 9$) were determined to be the progenitors of the allopolyploid species *B. juncea* (AABB, $n = 18$), *B. napus* (AACC, $n = 19$), and *B. carinata* (BBCC, $n = 17$), in a relationship known as "U's Triangle" (Figure 1). Among these species, distant hybridization can occur naturally or artificially. For example, *B. napus* is a compound species newly derived from *B. rapa* and *B. oleracea* after interspecific hybridization and spontaneous doubling of chromosomes.

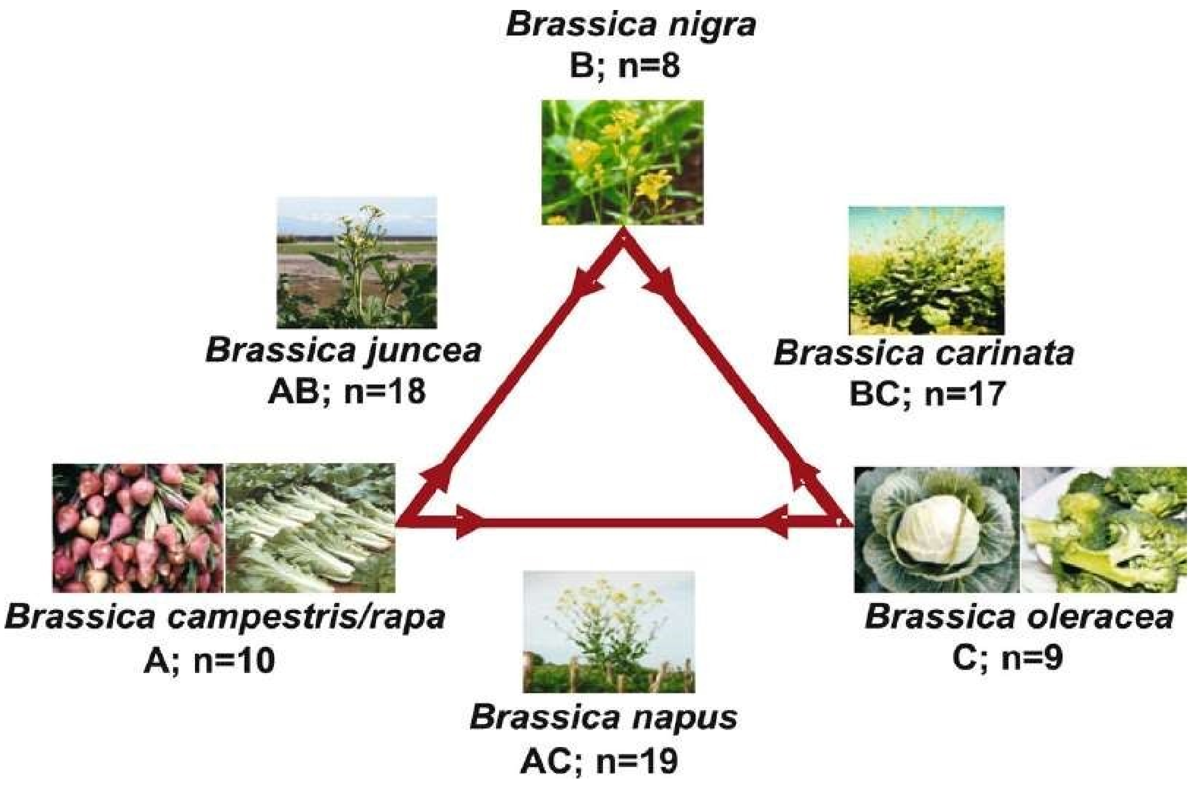

Figure1: U triangle of origin of crop Brassicas

Application of distant hybridization in brassica crop improvement:

Wild species or wild genetic resources are the potential sources of desirable genes for various characters of *brassica* crop plants. Wide crossing is an effective method of exploiting desirable characters from wild species for the improvement of cultivated *brassica* crop plants. Thus the significance of wild species and distant hybridization are interlinked. Distant hybridization has played significant role in (a) Disease resistance, (b) Quality, (c) **Yellow**

Seededness, (d) Mode of reproduction, (e) **Other traits of agronomic interest,** (f) Novel genotypes and (g) development of commercial hybrids.

(a) Disease Resistance:

Distant hybridization has been instrumental in transferring disease resistance from wild species into cultivated ones. For example, use of the B-genome as a source of resistance against *Leptosphaeria maculans* from diploid and tetraploid species. High resistance from *B. juncea* was obtained in selected recombinant lines of *B. napus* carrying a resistance gene located on chromosome B8. Successfully introgressed a B-genome chromosome from *B. carinata* to *B. napus*, with plants carrying this chromosome showing variation in traits such as blackleg resistance, days to flowering, days of maturity, and fatty acid composition. The improvement of resistance against *Erysiphe polygoni* resistance was successfully demonstrated in hybrids between *B. carinata* (donor) × *B. oleracea*. Transfer of black rot resistance from *B. carinata* to *B. oleracea*, resistance to *Brassica* leaf blight caused by *Alternaria brassicae* from *B. hirta* to *B. juncea* and transfer of powdery mildew resistance from *B. carinata* to *B. oleracea* through embryo rescue followed by back crossing to *B. oleracea*.

(b) Improvement in Oil Quality Traits:

Oil quality characters have also been successfully transmitted between species for crop improvement in *Brassica*. In rapeseed, low erucic acid and low glucosinolate content originate from two *B. napus* cultivars: “Liho” with low erucic acid and “Bronowski” with low glucosinolate content. Another possible source of these oil quality traits is *Capsella bursa-pastoris*, which can show less than 1% erucic acid and less than 16 µmol/g of glucosinolates in the seeds, as well as high resistance to *Sclerotinia sclerotiorum*. Several chromosomes and chromosomal fragments from *C. bursa-pastoris* were successfully introgressed into *B. napus* and *B. rapa*. Another wild relative with favourable fatty acid content is *Orychophragmus violaceus*, which has been successfully crossed with *B. napus*.

(c) Yellow Seededness:

Yellow seededness is a desirable trait in *Brassica*, as yellow seeds have less fiber, higher protein, and higher oil content than black seeds. Although *B. juncea* and *B. rapa* contain yellow-seeded traits, this trait is not found in rapeseed (*B. napus*). Using monosomic alien addition lines from the cross *B. rapa* × *B. oleracea*, found that seven of the nine C chromosomes carry genes that affect seed color, showing the complexity of this phenotype. Interspecific crosses between *B. alboglabra*, *B. rapa* var. “yellow sarson”, yellow seeded *B. carinata* and black seeded *B. napus* have been carried out to produce yellow-seeded *B. napus*, with interspecific hybrid progeny showing different degrees of seed colour.

(d) Mode of reproduction:

Male Sterility is the most common alteration in the mode of reproduction which results from interspecific hybridization. Cytoplasmic male sterility is an economic device for hybrid creation and hybrid seed production. The most successful example of this approach in *Brassica* is the Ogura CMS system, where alien cytoplasm was achieved from crossing *Brassica napus* to Japanese radish (*Raphanus sativus*). This system was subsequently widely used in *B. napus*, *B. juncea* and *B. oleracea*. Several other CMS systems have also been successfully developed from interspecific hybridization events, including a novel CMS system in *B. juncea* incorporating the cytoplasm of *B. fruticulosa*, and the Nsa CMS system in *B. napus* utilizing *Sinapis arvensis* cytoplasm. Protoplast fusion has been used to transfer *Ogu* cytoplasmic male sterility factor from *Brassica napus* to *Brassica* juncea and for the improvement of male sterile lines in hybrid breeding systems. Somatic hybridization between *B. juncea* and *B. oleracea* has also been used to transfer cytoplasmic male sterility and resistance to Turnip mosaic virus from *B. oleracea* to *B. juncea.* achieved stable CMS *B. juncea* and an introgression line carrying the restorer gene via somatic hybridization between *M. arvensis* and *B. juncea* followed by backcrossing with *B. juncea*.

(e) Other Traits of Agronomic Interest:

There are several other desirable characters which have been transferred from wild species to cultivated brassica crop plants. For example*, Moricandia arvensis* is a plant that expresses an intermediate C_3–C_4 photosynthetic mechanism. This trait was introgressed into *B. napus* by somatic hybridization and obtained three hybrid plants that expressed C_3–C_4 intermediate photosynthesis characteristics. Dwarfism is a useful agronomic characteristic which helps avoid lodging which was introgressed from a mutant *B. rapa* into natural *B. napus* via production of a resynthesized *B. napus* from the mutant *B. rapa* with a normal *B. oleracea*, followed by four generations of backcrossing with natural *B. napus*. Pod shatter resistance has also been introgressed into *B. napus* from *B. juncea* via direct hybridization. Drought tolerance has been introgressed from *Sinapis alba* into *B. napus* by somatic hybridization, and was identified at the vegetative stage in the BC_3F_1 vegetation, although the original target was yellow-seededness.

(f) Novel Genotypes:

A combination of characteristic features of two unrelated species or genera through distant crossing could give rise to novel genotypes under domestication. *Raphano brassica* is an amphidiploid obtained from an inter-generic cross between *Raphanus sativum* and *Brassica oleracea* (Sharma,1994). *Brassica amarifolia* is an outstanding example where a new species was artificially synthesized though amphidiploidy (Narain and Prakash,1967) from an inter specific cross *B. tournefortii* x *B. nigra.* This new species is aphid tolerant. Prakash (1973) was also able to artificially synthesize B. juncea through amphidiploidization of the interspecific hybrid between *B. campesstris* and *B. nigra.*

(g) Development of commercial hybrids:

Improved hybrid cultivars have been developed through the use of wild species in *brassica juncea*. The hybrid between *Brassica napus* and *B. rapa* has many desirables features and is easily produced. It is likely that this interspecific hybrid would be use as a hybrid variety in nsome part of Europe.

Resynthesis of *brassica* allotetraploid crop species:

Interspecific hybridization has two major outcomes: introgression and speciation. While introgression transfers just a limited number of alleles, hybrid speciation produces a new hybrid species. Resynthesis is the process of reproducing an already existing species from its progenitor species. This is most often done to increase the genetic diversity of the existing allotetraploid species by incorporating some of the greater genetic diversity of the progenitor species. Resynthesis as a tool of crop improvement has many benefits. Polyploidy induced during the process of resynthesis can overcome crossing barriers due to endosperm failure in interploidy crosses. In the case of *B. napus*, geographic isolation, extensive breeding and selection for low erucic acid and glucosinolate content has further eroded the genetic diversity of this species. Resynthesizing the *Brassica* allotetraploids from their diploid parents is a means of increasing the genetic diversity of these species. *Brassica juncea* has also been resynthesized by crossing its progenitor species *B. rapa* and *B. nigra* to broaden the genetic base of this species. *Brassica carinata* has also been resynthesized from its progenitor species, with hybrids showing morphological variation potentially useful for crop improvement. These new synthetic polyploids are not usually being bred to become a new crop nor in competition with the elite varieties, but rather as a source of diverse new agronomic traits, where they are used to cross with and introgress these traits into high-performance cultivars.

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