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Role of conventional and biotechnological approaches for genetic improvement of cluster bean

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ABSTRACT

Cluster bean [Cyamopsis tetragonoloba (L.) Taub. (Syn. C. psoraliodes)], commonly known as guar and an important crop from family Leguminaceae, is grown under resource constrained situations for use as seed, vegetable and forage in arid and semi-arid regions. The seed of this drought-resilient legume contains galactomannan polysaccharide, used in wide range of industries, which has made this orphan crop a high-valued cash crop. Cluster bean shows limited variability for morphological and agronomic traits. Narrow genetic base of cultivated cluster bean varieties and yield losses due to both biotic and abiotic stresses has hampered the intensive breeding efforts in cluster bean. Conventional breeding methods *viz.* induced mutations, wide-hybridization and induce male sterility have been employed to broaden the limited genetic base and for genetic improvement of cluster bean. Due to its pivotal role in rainfed agriculture, research efforts using biotechnological interventions like molecular markers, tissue culture and transformation have been initiated to boost the varietal improvement but development of these tools are still at early stage in cluster bean. This article attempts to summarize and discuss the recent progress made in mutation breeding, distant hybridization, DNA marker studies, development of in-vitro propagation system and genetic transformation protocols.

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1. Introduction

Globally cluster bean/guar (*Cyamopsis tetragonoloba*, 2n = 14), a member of family Leguminaceae, is an important crop of arid and semi-arid regions (Kumar et al., 2015). It is believed that geographic

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centre of origin of cluster bean is India although no wild species has been reported in country. Gillette (1958) pointed out that tropical Africa is its probable centre of origin as wild species were found to occur in that region. Due to deep rooted system, this short duration, hardy and drought resilient legume is extremely adapted to the inhospitable environment of rainfed regions. This ancient legume is mainly cultivated for feed and food (Singh and Dahiya, 2004) therefore providing nutrition to both mankind and animals. It is used for human consumption and cattle feed (30–40%), industrial purpose (50–55%), medicinal (5%) as well as for soil improvement and other miscellaneous purposes. Due to multiple usages and presence of gum in its seeds, cluster bean has been emerged as a unique high-valued commercial crop.

Cluster bean is predominantly autogamous and bears beans or pods in clusters, hence named as cluster bean. The light-grey, pink, white or black coloured seed consists of 43–47% germ, 35–42% endosperm and 14–17% husk (Goldstein and Alter, 1959). In cluster bean seed, nearly 90% (w/w) portion of the spherical-shaped endosperm is deposited with galactomannan gum –a polysaccharide synthesized in Golgi apparatus (Dhugga et al., 2004). In cold water, this odourless polysaccharide forms a thick colloidal solution (Das and Arora, 1978). Galactomannan gum has a genetically controlled ratio (1:2) of galactose to mannose (Sandhu et al., 2009). The gum consists of a mannose framework with a galactose group attached to it and act as reserve of glucose to be used by the seed during germination. Cluster bean gum has diversified uses such as in textile, ore-/metal-refining, paper, coal-mining, petroleum drilling, cosmetic and pharmaceuticals, explosion manufacture, potash purification, tobacco and food enterprises (Punia et al., 2009; Kuravadi et al, 2013). It is an integral part of the natural gas exploration process known as a hydraulic fracture. Due to hydrophilic and swelling nature, the gum and its derivatives in various forms such as coatings, matrix tablets, hydrogels, and nano- or micro-particle have found their use in developing slow releasing and targeted drug delivery (Prabaharan, 2011). Cluster bean is also being utilized to cure diabetic and lipoproteins/cholesterol patients (Kumar et al., 2013).

Cluster bean requires reasonably warm weather and moderate rainfall for its growth and therefore, it is mainly cultivated as a cash crop in the Indian subcontinent (India and Pakistan). Though, to a narrow extent, the crop is also under cultivation in Australia, Bangladesh, Myanmar, USA, South Africa, Brazil, Congo, Sri Lanka (Boghara et al., 2015). Due to abrupt and unexpected rise in demand of guar and its gum in recent years, its cultivation has extended to resource rich regions and alternative seasons under proper management (Kumar et al., 2015). The chief importer of guar gum and its derivatives is Australia, Austria, Brazil, Canada, China, Chile, Germany, Greece, Ireland, Italy, Japan, Mexico, Portugal, Sweden, UK and USA (NRAA, 2014). The annual world's total cluster bean gum and its derivatives production is around 0.75–1.0 million tonnes. Globally, India ranks first in production as producing about 75–82% of the world's cluster bean followed by Pakistan (10–12%). In India, with 75% of total production, Rajasthan is the top cluster bean producing state.

In spite of its importance, the productivity of this crop is very low and hence there is need to enhance the yield of cluster bean. Lack of suitable early maturing high yielding varieties, an incidence of many fungal and bacterial diseases in rainfed cultivation, improper time of sowing, inadequate fertilization and improper agronomic practices are major production constraints for adequate production of this versatile crop. Therefore, there is an urgency to design breeding approaches aiming at developing proper plant architecture coupled with tolerance to abiotic and biotic stresses in order to stabilize the yield of guar at higher level of production. At the morphological level, cluster bean germplasm showed variability (Saini et al., 1981; Mishra et al., 2009; Pathak et al., 2011c) but this variability is not sufficient for stress tolerance and gum content. Therefore, broadening the genetic base and developing stress tolerant varieties with high galactomannan content is restricted due to inadequate variability available for these traits. Thus, along with various conventional breeding approaches like mutation breeding, distant hybridization, male sterility etc, there is urgent need to explore non-conventional genetic improvement approaches like molecular marker, tissue culture and genetic transformation technologies. This article reviews the conventional breeding work done, highlights the current role of biotechnology and its future prospects to enhance production and productivity of cluster bean through genetic improvement.

2. Genetic improvement of cluster bean through conventional approaches

2.1. Genetic diversity and germplasm resources

The availability of genetic diversity and its successful collection, maintenance, utilization and conservation is pre-requisite for crop improvement program (Poehlman and Sleper, 1995). The genetic variability existing in cluster bean germplasm has been evaluated by using various morphological and biochemical traits. Conspicuous morphological variations are displayed for branching (branched/unbranched), pubescence (hairy/smooth), pod shape (straight/sickle), growth habit (determinate to indeterminate), pod bearing pattern (regular/irregular) (Saini et al., 1981). In India, the exhaustive catalogue by Dabas et al. (1989) has provided information on fifteen morpho-physiological and yield traits along with place of collection for all 3580 accessions. Many important traits like plant height (46.75–239 cm), clusters per plant (1.75–64.5), pods per plant (2.25–262.35), pod length (1.85–19.3 cm), seeds per pod (4.15–13.0) days to maturity (128–185 d), seed yield (0.95–59.7) and 100 seed weight (1.9–4.75 g) showed a high degree of diversity. Though, there was paucity of early flowering and maturing genotypes in this collection but was later on enriched by many collections evaluated at Regional Station, National Bureau of Plant Genetic Resources (NBPGR), Jodhpur, India where certain genotypes flowered as early as 28 days and matured in 70 days. Many other studies involving comparatively limited genotypes though reported considerable diversity towards desirable direction but with reduced range (Mishra et al., 2009; Pathak et al., 2011a, 2011c). Plant height and branches per plant on a higher side are important as they bear more clusters and branches (Dabas et al., 1989). High level of diversity for yield traits viz. number of pods, clusters etc. have also been reported by many studies along with other morphological traits (Mittal et al., 1977; Dabas et al., 1982; Henry and Mathur, 2005; Mahla and Kumar, 2006; Pathak et al., 2009; Pathak et al., 2010a; Kumar et al., 2014; Girish et al., 2012; Sultan et al., 2012; Manivannan and Anandakumar, 2013; Manivannan et al., 2015; Kumar and Ram, 2015). Morris (2010) characterized 73 accessions collected from India, Pakistan and USA; and reported enough genetic variability pod length (32–110 mm), 100 seed weight (2.3–4.8 gm) and number of days to 50% maturity (96–185 days).

Despite of commercial importance, biochemical studies on gum content are limited. The remaining part of seed comprising of seed coat and protein rich germ makes good animal feed. A few studies have indicated some extent of diversity in these biochemical and nutritional traits. Pathak et al. (2009) reported considerable variation for endosperm proportion (30.4–46.3%), gum content (23.9–34.2%) along with crude fibre (4.1–8.0%), oil (1.8–5.2%), crude protein (28.3–35%), carbohydrate (38.8–59.1%) and minerals (3.5–6.0%). However, comparatively narrow range was obtained by Kays et al. (2006) for dietary fibre (52.4–57.7%),

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