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Client oriented breeding: An approach to improve moisture stress tolerance in lucerne

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Abstract
Client oriented breeding (COB) offers manifold advantages as compared to research station breeding in terms varietal adoption and acceptance by farmers in marginal regions. Interaction of breeders and farmers has identified key traits with high impact potential including enhanced water-use-efficiency, tolerance to biotic and abiotic stresses, increased biomass yield, nutritional quality, and persistence. The simplest approach to abiotic stresses tolerance breeding is also the most effective especially in forage crops. It is to select for biomass yield which is the integrating complex trait and to carry out the selection in a representative stress environment. It can be more efficient by carefully managed stress screening and by carefully choosing parents of crosses so that various physiological traits can be pyramided. This implies a reduction in the number of crosses that are made so that larger population can be employed, an approach that has been effective in the breeding of stress tolerant, widely adapted in crop plants. Potential benefits of client oriented breeding have been a source of widespread interest and resulted in numerous efforts to achieve the desired synergy amongst different aspects. Presently wide hybridization with selection in the target environment offers the best opportunity for widening the genetic base for stress resistance for sustainable goal. Polycross nursery programme has been used in developing new composite/synthetic varieties of lucerne by various organizations and the methodology can be extended for enhanced level of moisture stress tolerance as compared to existing varieties. Integration of client oriented and molecular breeding approaches and the latest technologies may also contribute to the sustainability of profitable forage crop production systems to meet current and future demands for these crops.

Keywords: Abiotic stress, Alfalfa, Client oriented breeding, Moisture tolerance, Polycross nursery

Introduction

Since three decades the contribution of agriculture in national economy is in declining mode. The time has now come to arrest the downward trend of agricultural contribution in the national economy. This is more pertinent as the livelihoods of more than 55% population depend on agriculture and animal husbandry. It has been estimated that the world's farmers will have to produce as much food in the next 40 years as has been consumed since the beginning of humanity. One of the ways to strengthen the national economy is to increase the productivity of animals through increased availability of feed and fodder. Testimony to this is the increasing trend of dairy products requirement of the modern world. At present we are in short supply of green fodder (35%), dry residues (11%) and feed supply (44%) (Anonymous, 2013). These convince us the need to develop varieties having better yield along with adaptation to biotic and abiotic stresses. Out of the total cultivated area under fodder crops more than major area is covered by sorghum, berseem, lucerne, maize and pearl millet. A little quantum jump in any of these crops will ultimately pave the way for increased availability of animal products for mankind. One of the ways to increase the availability is to breed farmer preferred high yielding fodder crops varieties. Adaptive mechanisms like abiotic stresses tolerance need to be developed in order to increase the forage crops productivity through traditional crops in non-traditional niches and non-traditional crops in traditional ecologies. Both conventional and biotechnological technologies needed to effectively meet the challenges.

In comparison to traditional breeding, farmer participatory approaches in plant breeding result in a better orientation to the needs of the client farmers. In the past, such approaches have been described by the activity of involving farmers– participatory plant breeding (PPB). We now prefer to use a term that explains the purpose of involving farmers– highly client-oriented breeding (COB).

Objectives of COB

The objectives of COB are well defined in the process of participatory plant breeding (PPB). PPB (Witcombe *et al*., 1996) has been advocated for decades. Morris and Bellon (2004) categorised the types of PPB and defined 'efficient PPB' as having farmers involved both at the initial stage of setting goals and in the later stage of testing varieties but breeders alone were responsible for the cultivar development stage. Witcombe *et al.* (2005) attempted to remove the artificial dichotomy of PPB and conventional breeding by defining the purpose of farmer involvement– improved client orientation– using the term client-oriented breeding (COB). All programmes have to be client oriented to some extent – although some fail because the breeding targets simply do not match farmers' needs. They analysed the methods that could be used to achieve explicitly an improvement in client orientation and reviewed the extent to which they were used in breeding programmes. Highly COB will often be identical to the efficient PPB of Morris and Bellon (2004), and the terms PPB and COB are used interchangeably where COB always referring to efficient PPB. Genotype x Environment (G x E) which is main reason for the limited success of plant breeding efforts under marginal environments is addresses more emphatic way while utilizing COB approach of cultivar development.

Need of COB in lucerne

Lucerne being highly cross pollinated crop, conventional and heterosis breeding attempts have proved unsuccessful, to come out with fruitful results, it is quite likely that COB may prove to be successful. Irrigation water requirement is a primary requisite for alfalfa production and water is becoming a precious commodity in present scenario of climate change, to come out with moisture tolerant variety is the requirement of the day. Secondly, lucerne is also one important forage crop which tolerates soil salinity to some extent and cultivated in a large area in the coastal belt of western India. However the extent of yield reduction due to moisture and salinity stress is yet to be ascertained. COB have been recognized more better option for evolving adoptable and acceptable varieties in such a scenario because it involves target environments in all the steps of breeding programme.

The complex molecular basis of tolerance to environmental stresses, often quantitative in nature, provides a challenge to plant breeding (Morgante and Salamini, 2003). We remain optimistic that functional genomics will contribute greatly to bridging the gap between phenotype and genotype in the context of breeding for complex traits such as adaptation to abiotic stresses.

Enhancing dry matter yield productivity in forage crops

The rate of genetic improvement in total annual yield of dry matter harvested through plant breeding in forage crops has been low as compared to food grain crops in 20th century. The factors responsible for such situation are-

- Emphasis on increased harvest index for increased grain yield by reducing the other plant characteristics;
- the life cycle of grain crops is short as compared to forage crops;
- the importance to traits other that total annual dry matter yield in forage crops;
- limited efforts on heterosis breeding except synthetic cultivars in breeding forage crops and
- dependency on by-products of major food grain crops as animal feed with special reference to Indian situations

Here the first objective is to emphasize the importance of COB in present day scenario of varietal development and their adoption and the second is to explore the possibility to use the methodology of polycross nursery for the development of moisture stress tolerant varieties in lucerne crop.

Client oriented breeding

In COB, varieties selected by farmers are used as parents of crosses because they are adapted and acceptable (Fig. 1). COB is more powerful because it provides opportunities for creation of rare recombinants and ample variability rather than relying on existing varieties. Farmers sometimes identify specific weaknesses in a variety; these can be eliminated by crossing it with a parent chosen for its complementary strengths. Advantage of COB is that it is much faster than conventional breeding because new varieties are immediately tested with farmers.

Each stage of COB is designed to better account for the needs of the clients (Witcombe and Yadavendra, 2004)-

- The new variety is specifically designed to have the combination of traits that the client farmers desire.
- The parents are very carefully chosen on the basis of having the potential to produce this desired combination. At least one is locally adopted by farmers.
- The selection in the segregating generations is done in environments that closely match the fields of the client farmers.

• The results of this selection, new varieties, are immediately tested with the client farmers in the area for which they are bred.

The varietal development is not a new aspect and practiced since times in different ways depending upon the crop, its usages and the area of its adoption. In lucerne, poly-cross nursery programme has been a source of developing synthetic varieties. A synthetic variety is that developed by crossing, compositing or planting together two or more unrelated stains or clones, the bulk seed is harvested and replanted in successive generations. By natural inter-crossing the unrelated strains or clones are "synthesized" into a new variety (Tysdal *et al.,* 1944).

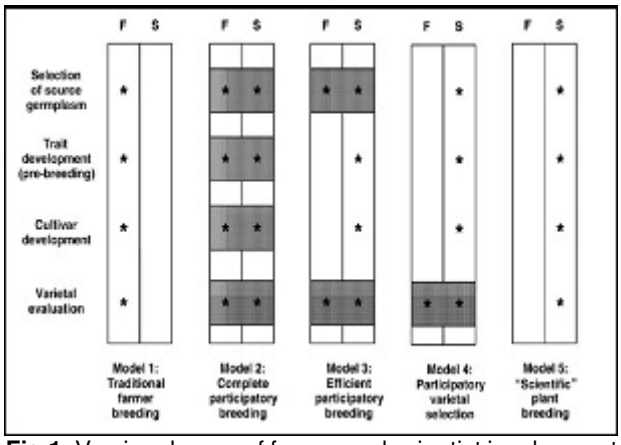

Fig 1. Varying degree of farmer and scientist involvement in breeding programme

COB is a product innovation approach which involves the following steps-

***a. Product design*:** This involves the setting up of the goal. In varietal development we design the variety on the basis of the requirement of the farmers. We ask the farmers what he wants. The farmers' requirements are based on the Participatory Rural Appraisal (PRA) and Participatory Varietal Selection (PVS) (Yadavendra *et al.,* 2006). Drought tolerance, extreme earliness, and tolerance to low fertility identified by PRA and from variety testing (PVS).

The majority respondents from the above exercises may prefer to have the following traits in a fodder variety:

- Higher biomass yield
- Deep root system (root length)
- Early vigour
- Abiotic stress tolerance
- Better fodder quality

The design envisaged: Moisture stress tolerant variety of lucerne with high fodder yield.

Requirements: Well adapted varieties (3-4) in TPE (female) and donor parent (male) for moisture stress tolerant traits like root length and leaf parameters. Involvement of plant physiologist in screening process is essential for moisture stress breeding programme like plant protection scientists in biotic stresses.

***a. Product development*:** After designing the variety, we plan the methodology for the development of the variety. This depends on the crop we are handling and involves fundamentals like identification of donor parents, target environment and the methodology adopted for incorporating the required traits. Use smart crosses and select in target environment (if required simulate target environment). Clever crosses (a single composite). Selection on stress-prone farmers' fields and created target prone environment (TPE).

Identify the donor parents for abiotic stress tolerance/ resistance (moisture) of varying degree especially selected from the germplasm collected from stress prone regions and use them in varietal development. Methodology for developing abiotic stress tolerant/ resistant variety of lucerne using polycross nursery is given in this paper. The involvement of plant physiologist is envisaged at appropriate stages of the varietal development.

***b. Product testing*:** Once the product is developed *i.e.* outcome through the process of product development, it need to be tested with the clients after the preliminary requirements are met. Also conduct trials also with the farmers (PVS) in TPE. It is desirable to involve clients in the product evaluation to develop a preferred product.

***c. Product marketing*:** After the successful testing of the final product and its release, using appropriate extension tools, popularization amongst the clients is undertaken for awareness of its superiority over the existing product for wider adoption. Dissemination amongst farmers through FLDs, cooperative dairies and NGOs.

***e. Customer feedback*:** The product has been floated in the market with sufficient popularization for mass adoption by the clients. After a given period of time, the feedback of the all users (stake holders) including innovators as well as end users is collected. On the basis of this primary information and the secondary information collected from the documented official records will help

in estimating the assessment of adoption. Assess adoption through surveys in a structured format.

Advantages and impact of client oriented breeding

***a. Farmer's preferred*:** The product from the COB will be farmer preferred variety over the existing ones. Client farmers are aware of the product as they were involved in the product development process.

***b. Faster Dissemination*:** The spread of the variety developed through COB is faster due to its testing at farmers' fields during the process of development and availability of its seed (Mottram, 2004). The seed dissemination is much faster from farmer to farmer than any other extension mechanism. An example of rice variety BVD-109 bred through COB by Birsa Agricultural University was also recommended in eastern Gujarat, western Madhya Pradesh and southern Rajasthan (Yadavendra and Witcombe, 2013). The varietal spread (Fig. 2 and 3) from farmer to farmer in Banswara, a tribal district of Southern Rajasthan, was studied at farmers' fields as given below (Conroy *et al.,* 2008).

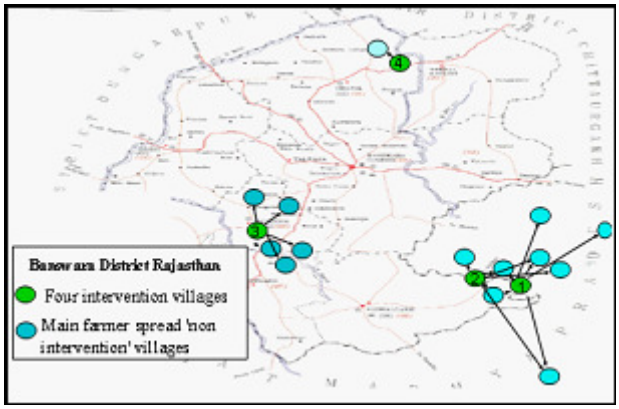

Fig 2. Village to village spread of rice variety BVD 109 in southern Rajasthan

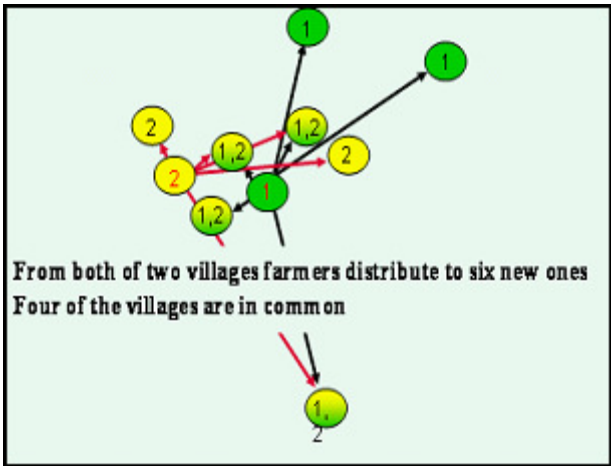

Fig 3. Farmer to farmer seed spread from two villages

c. Wider adoption: The client oriented bred varieties are widely adopted not only for the region they are bred but in other similar agro-ecological niches. This is mainly due to the fact that the seed is produced and made available on demand. This has happened in case of maize variety Gujarat maize-6 released by main Maize Research Station, Gujarat Agricultural University, Godhra, Gujarat (Yadavendra, pers. commun.). This composite variety was developed through client oriented breeding procedure and released in 2003 but the testing at farmers' fields was also done during the process of its development (Witcombe *et al.,* 2003). As a result the spread was quick and wider adoption in large area as can be seen from the Figure 4 below (Witccombe and Yadavendra, 2014).

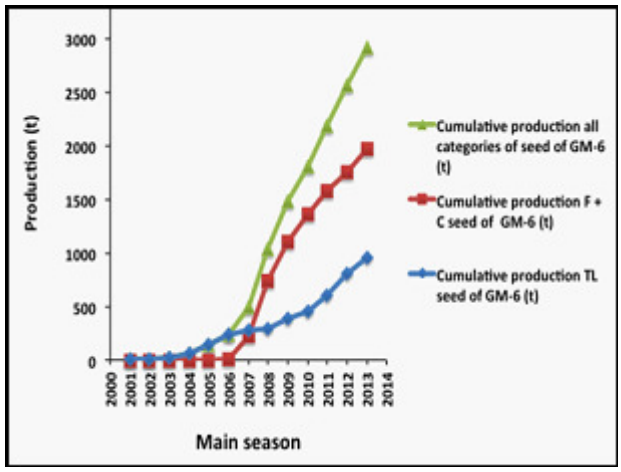

Fig 4. Cumulative production of different stages of maize GM-6 seed

COB for moisture stress tolerance in lucerne

Attempting to breed for marginal conditions, yield is of secondary importance as compared to adaptation but there is often a negative correlation between these characters. Drought is the most devastating abiotic stress affecting crop productivity, which is caused by insufficient rainfall and/or altered precipitation patterns. Tolerance to drought is a complex quantitative trait controlled by several small effect genes or QTLs and is often confounded by differences in plants phenology. To address the complexity of plant responses to drought, it is vital to understand the physiological and genetic basis of this response. Since cultivation of alfalfa is in areas where availability of water is assured and requires a good amount of water for satisfactory green biomass tonnage. The saving of water at a given stage of the crop growth may result in an additional advantage in alfalfa production by reduction in production cost. An inherent advantage in lucerne production is its moderate salt sensitivity. Given

this factor, considerable work has been done using recurrent phenotypic selection to improve moisture stress tolerance. Various plant mechanisms in lucerne are responsible for moisture stress tolerance at germination, crop establishment stage and cutting stages. Multiple cycles of selection at different stages is required to improve adaptation to stress conditions. Efficient recurrent cycles of selection are made from the heterozygous population for important growth parameters followed by yield selection over multiple cuttings result in significant improvements in total green biomass. Selections are then incorporated into elite populations using phenotypic or genotypic recurrent selection. Synthetic cultivars are then developed by random crossing individual plants and harvesting equal quantities of seed from each parent, which is bulked to form the synthetic 1 generation. Using appropriate moisture stress tolerance screening methodology for the synthetic populations generated from polycross nursery may result in new cultivar development (Table 1).

Poly-cross nursery in lucerne is used in identifying high yielding lucerne synthetic varieties by BAIF, Urulikanchan and MPKVV, Rahuri in Maharashtra, Anand in Gujarat and Coimbatore in Tamil Nadu. The methodology given above may also be found useful in identifying the moisture stress tolerant strains in lucerne and may be suitable for identifying other abiotic stresses tolerant strains.

Conclusion

COB is a powerful accelerator of plant breeding progamme through conscious selection involving clientele who ultimately will grow developed variety. The participation of farmers in the selection process gives opportunity to improve those traits which a farmer also feels more important. Many widely adopted and popular varieties have been developed in different crops through participatory plant breeding. Outcome in alfalfa breeding can also be accelerated with manifold advantages by practicing COB instead of conventional/traditional breeding methodology.

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Table 1. Development of moisture stress tolerant variety of Lucerne using polycross nursery programme

Season	Activity
1	Select one established moisture stress donor parent and four widely adapted genotypes of lucerne chosen on the basis of the farmers' perceptions for polycross nursery.
2	Parents are planted in 5x5 Latin square design. Create manual flower tripping conditions to ease cross pollination. Harvest the seed separately from individual plants.
3	Individual plant progenies (7-10 thousand plants) are raised in isolation to allow random mating amongst them facilitated through manual tripping conditions. The planting is to be done in the field where screenings for a given level of moisture stress conditions are feasible. This provided a highly heterozygous population that makes selection effective. Select 2000-3000 superior plants with high biomass and harvest the seed from them individually.
4	Allow 2000-3000 plants progenies to mate randomly also conditions created for out crossing amongst these plants. Select 250-300 most promising plants showing tolerance to moisture stress along with high biomass. Harvest the seed separately.
5	The seed of 250-300 individual plants progenies sown for evaluation for different fodder quality parameters. Also invite the farmers to select the best plants of their choice. Retain the seed of best 50-60 plants from these progenies.
6	The best selected 50-60 plants progenies are screened for given level of stress based on the moisture stress level tolerance under field conditions. Select the best performing progenies observed to posses the desired level of stress tolerance without compromising the GFY and DMY standards. Harvest the seed from 4-5 selected plants progenies. If The bulked seed of these 4-5 progenies is not sufficient, ratoon crop can also be raised for more seed.
7	The 4-5 progenies bulked seed is grown under isolation and allowed to mate randomly to produce the sufficient seed of new synthetic strain.
8	Evaluate the new strain in the formal system across locations over years and also on farmers' fields for release.

the logistics for undertaking the maize survey in Gujarat, MP and Rajasthan.

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