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Evolving Seed System for System of Crop Intensification: Policy Needs

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Abstract

System of Crop Intensification (SCI) evolved as an extension of applying the principles of System of Rice Intensification (SRI) to other crops, aims at improving agronomic performance while conserving and enriching the natural resources. It is largely presumed to be crop and variety neutral. Crop performance is a function of genotype and environment. Ideal plant type of released varieties in several crops is conceptualized, developed and evaluated in monocropping system and not tested for SCI needs. Success of any crop improvement program depends on setting up of priorities based on community needs and consumer preferences. There are few examples of demonstrating release of farmer varieties through participatory varietal selection (PVS) and participatory plant breeding (PPB). Specific plant type suitable and breeding approaches for SCI are briefly discussed. An attempt is also made to address the need for linking SCI with identification of suitable genotype, ensuring access to quality seed supported by an appropriate seed system in place and to highlight the policy needs in the context. An alternative seed system for the varieties identified for SCI is proposed.

Keywords: Crop intensification, seed system, traditional varieties, crop improvement and Seed Systems policy

Introduction

Crop improvement, is an age old dynamic evolutionary process of utilizing genetic diversity based on communities' needs and preferences. The conventional breeding procedures aim at developing improved varieties or hybrids or transgenics targeting mostly high yield or quality. Such developed varieties are linked to institutionalised seed system. Strategies largely follow top down approach. Farmer participatory approach is a recent development but is still not practiced at scale. Green revolution in India succeeded in meeting the historical need to achieve food security. Crop improvement process in Green Revolution was focused on exploitation of genetic potential in response to inputs (seed, water, fertilisers, pesticides etc.). Over time inputs were indiscriminately used leading to soil, water, climate and biodiversity emergencies. Exploitation of genetic potential reached its limits with available strategies and productivity stagnation is of common experience in several crops.

In view of global focus on agroecological farming, there is also a need to relook at varietal performance in the context of nature-based package of practices; called agro-ecological, regenerative, organic or natural farming. There are evidences that under such nature based farming practices, traditional varieties outperform formally notified varieties. SCI has potential to enhance yield of selected crops with positive benefits to ecology and environment. Significant evidence is also accumulated on the success of SCI in selected crops.

However, the effort of exploring the genetic potential of crop varieties that respond to SCI needs to be focused with appropriate policy support. Location specific, highly domesticated landraces which co-evolved over time with the eco-system may have heritable traits suitable for SCI but need to be validated. In-situ conservation and evaluation followed by varietal development and identification of such traditional varieties is the need of the hour. In order to make the quality seed of selected varieties accessible to farmers an effective alternative seed system is required.

The system of crop intensification (SCI) which emerged from the experiences of System of Rice Intensification (SRI) provides a modified strategy for "sustainable intensification" to meet the global food security. SCI is successful in a wide range of crops like rice, finger millet, wheat, sugarcane, tef, mustard, soya bean, kidney bean and several vegetables (Abraham *et al.,* 2014). As per Abraham *et al.,* 2014, in SCI, agronomic management relies on early transplanting, wider spacing or reducing crop density, soil enrichment with organic matter and better water management. The emphasis is on allowing each plant more room to grow both above and below ground. The success of any crop improvement program does not rely on genotype (G) or environment (E) alone but on good combination of G x E. In SCI, effect of E prevails over G and identification of heritable and stable traits over modified agronomic management is the key step. A re-orientation of varietal development in the context of changing climatic scenario and SCI is essential.

The present centralised system of varietal evaluation and release is restricted to improved varieties which are highly homozygous and homogenous and are often vulnerable to biotic and abiotic stresses. In the context of changing climatic scenario and rampant nutritional insecurity, landraces or traditional varieties which co-evolved over time within the eco-system gained importance. The scope of present seed system catering to the needs of formal sector can be further widened to fit into the emerging seed needs of SCI. The present paper is an attempt to highlight policy needs for an alternative seed system.

Crop Improvement and SCI

Crop improvement activities over the decades have been tuned to reorient the objectives and meet the global challenges of food security. Sustainability, nutrition, climate and pest resilience are gaining importance as breeding objectives in the recent past. The System of Crop Intensification (SCI) aims to achieve higher output with less expenditure on land, labor, capital and water by making modifications in crop management practices (SRI-2016). Four principles of crop management practices broadly included to (i) establish healthy plants both early and carefully, taking care to conserve and nurture their inherent potential for root growth and associated shoot growth (ii) reduce plant populations significantly, giving each plant more room to grow both above and below ground (iii) enrich the soil with decomposed organic matter, as much as possible, also keeping the soil well-aerated to support the better growth of roots and of beneficial soil biota and (iv) apply water in ways that favor plant-root and soil-microbial growth, avoiding hypoxic soil conditions that adversely affect both roots and aerobic soil organisms (SRI, 2016). SCI does not rely only on smart crop varieties that yield with inputs; but, need robust and sustainable genotypes that can efficiently utilize early establishment, wider spacing, better water and nutrient management. Any additional growth, both above and below ground, need to be carefully exploited with minimum loss due to pests and diseases. Among the major crop management practices of SCI, reducing plant populations and enriching the soil with decomposed organic matter with better soil and root management are applicable to even direct seeded rainfed crops.

SCI and relation to plant types

Plant architecture or plant type concept until now has been framed for solo cropping with crop wise optimum plant population. Most modern high yielding varieties, bred specifically for monoculture, may not be suitable for diverse cropping systems (Bourke *et al.,* 2021). Plant type needs of high density adaptation such as short stems, few tillers and erect leaves are different from low density adaptation needs such as high tillering and prostrate leaf stature (Donald, 1968). High yielding cultivars at high density lose their advantage at low density (Reynolds *et al.,* 1994). Performance of genotypes at low density is mostly linked to the plasticity of traits especially tillering and size of upper leaves in comparison to the normal density. Further, in rainfed situations, cropping systems needs are different from irrigated mono cropping approaches. Intercropping, mixed cropping and poly-cropping approaches are often required not only to harness the natural resources efficiently but also to cater to the nutrition and livelihood needs of small holder rainfed farmers.

Selection of best performing genotypes in pure stands relies on a two-dimensional approach where in competition between plants for soil (land) and light (plant height) is considered. In SCI approach, additional dimension of crop competition for both shoot and root growth are added. Present breeding approaches largely ignore the benefits of positive inter- and intra-specific interactions between crops or genotypes and ignored the traits modified with companion crops (Bourke *et al.,* 2021).

Several studies established the merit of crop intensification by mixing species or genotypes in a range of possible spatial and temporal arrangements, over monoculture in terms of efficient nutrient uptake and biocontrol (Boudreau, 2013, Li *et al.,* 2014, Brooker *et al.,* 2015). This may be due to the complimentary uptake of either water or nutrients, when the root systems are spatially or temporally separated

(Henry *et al.,* 2010; Postma and Lynch, 2012) or light capture and light use efficiency due to differences in shoot architecture and photosynthetic efficiency (Stomph *et al.,* 2020, Yu *et al.,* 2015). Efficiency of crop intensification is also measured in terms of reduction in occurrence of weeds due to their early suppression, low incidence of pests and diseases due to host dilution, allelopathy, microclimate, physical barrier effect due to combination of multiple crops (Ampt *et al.,* 2019).

Plant traits which are beneficial in a specific cropping pattern may not be suitable in another pattern due to three types of plant to plant interactions (i) Competition (ii) Complementarity and (ii) facilitation leave behind positive intercrop performance (Li *et al.,* 2013, Li *et al.,* 2014). Ecological perspective coins the process as "niche differentiation" where species evolved to avoid each other's specific niches or direct competition (Meilhac *et al.,* 2020) through a specific trait called plasticity. It is the ability of a plant to morphologically adapt its phenotype to a particular environment. In SCI models, plants tend to be more plastic compared to normal cropping, as they face different micro climate both above and below ground coupled with vigorous root and shoot growth. Plasticity of traits involved in competition like root growth, leaf size, leaf angle or orientation, petiole length, stem growth may be further enhanced through breeding efforts.

In a field experiment, five commercial winter wheat cultivars possessing unique architectures were grown under narrow (NI, 17.5 cm) or wide intercrop rows (WI, 35 cm) at the same population density (170 seeds/m^2) in France. Phenotyping included traits related to development (leaf emergence, tillering), morphology (dimensions of organs, leaf area index) and the geometry (ground cover, leaf angle, organ spreading and orientation). WI led to lower number of tillers compared to NI and later compensated by lower tiller mortality. Genotypic differences were also observed while understanding plant responses to spatial heterogeneity in addition to novel information to simulate light capture in plant 3 D models (Abichou *et al.,* 2019). There is huge diversity available among the traditional varieties for a variety of crop intensification systems and cropping system needs. Authors therefore propose that policy based efforts be directed to study and select among the local traditional varieties along with the traditional knowledge as priority for SCI.

Functional-Structural Plant (FSP) Modelling

Traditional crop modelling concepts restrict the combinations of species phenotypes for crop design optimisation due to limited parameters for phenotyping the species and altering the plant arrangements. In FSP models, plant development, growth and architecture are simulated in 3D over time and governed by effects of competition for light, water and nutrients (Bourke *et al.,* 2021). The FSP model is mainly developed to record plant development traits like leaf size and angle, stem length, root branching and thus ideally suited to explore the interaction between plant traits, arrangement and performance in tomato monocrop, wheat-pea mixtures, root traits in single bean plants (Bourke *et al.,* 2021). Further details of both above and below ground processes in FSP help in arriving at a combination of species phenotype and plant arrangement.

Breeding approaches for SCI

Ideotype breeding approach led to higher genetic gain for grain yield in rice than under selection for yield alone (Peng *et al.,* 2008). Ideotype breeding approach is a strategy to improve complex traits by changing simpler traits that are positively correlated with them and avoid unfavorable genetic correlations which offset the merits of traits related to ideotype (Breseghello, 2013). After the success story of semi dwarf rice, model plant type designed as a hypothetical ideotype or new plant type with few tillers, long panicle with >200 grains and lodging resistant thick stems however failed to outyield the best checks. In SCI, ideotype need to include a range of positive interaction effects that optimize collective performance. Brooker *et al.,* 2021 gave a detailed description of favorable interaction effects which is specific to context, crop and experiment conducted. In-silico ideotypes may also provide novel insights if traits (yet-unidentified) with significant agronomic impact are predicted (Louran *et al.,* 2020).

Conservation and evaluation of existing genetic resources is mostly confined to yield, yield components, biotic and abiotic stresses in many crops. SCI involves a complex interaction of G x E and it is crucial to identify heritable traits with additive genetic effects over a period of time. Several stable plant traits that contribute to SCI, need to be carefully identified. Genetic correlations between heritable traits under SCI need to be thoroughly studied to achieve further crop improvement.

In rice, tiller and panicle number are the key determinants of plant architecture even under SCI conditions. Genetic basis of tiller dynamics was revealed by genome-wide association studies using gene sequencing and SNP data set of Korean rice accessions (Zhao *et al.,* 2020). Genes involved in developmental phase transitions, along with genes modulating tiller development suggested rice tillering pattern at different growth stages (Zhao *et al.,* 2020). Such studies need to be initiated in crops that are highly successful under SCI system particularly finger millet that is proved double its yield in response to SCI (Srijit Mishra, 2020).

There are immense possibilities of exploring breeding approaches to develop genotypes that are suited to SCI. However, it is expected that screening the location specific and cropping system based traditional varieties may enhance the value of SCI and reap the benefits.

Seed Systems

A seed system is a set of activities related to seed production, access and use by farmers contributing to crop improvement. Standard formal seed production system aims at providing quality seed access to the farmer through a process monitored and regulated under the provisions of a national act.

Seed systems are often categorized into three types: formal, semi-formal, and informal. Formal seed production system in India with its standard seed production mechanism meets about 60 to 65% of seed needs while the remaining needs of farming community are met through an informal or semi-formal seed sector. Quality seed alone contribute 15-20% depending on the crop and there is a scope to further increase up to 45% with efficient management of other inputs.

Seed system components

A seed system includes a series of crop improvement activities contributing to variety development and seed production with an ultimate goal to cater to the needs of farmers. Sustained increase in agriculture production and productivity necessarily requires continuous development of new and improved varieties of crops and efficient system of production and supply of seeds to farmers. A robust institutional framework for seed production both in the public and private sector still is unable to meet the demand for good quality and quantity seed in time and at affordable price.

Farmers rely on farm saved seeds while seed replacement rate is as low as 10 per cent in some states for specific crops. The prescribed norms of Seed Replacement Rate are 33% for self-pollinated crops, 50% for cross-pollinated crops, and 100% for hybrids (seed net portal). It is an established fact that a strong co-relationship exists between seed quality, SRR and seed yield of crops. Seed quality essentially depends on genetic purity of varieties or parental lines maintained in different classes of seed *viz*., nucleus, breeder, foundation, certified and truthfully labelled (TFL) seed. As majority of the self-pollinated crops of cereals, pulses, oilseeds and millets operate through farm saved seeds or traditional varieties, the concept of seed classification is of not much concern.

Alternative Seed System

SCI, an unexplored and dynamic crop system still has scope to contribute to sustainable agriculture through reorientation of seed systems. In the absence of suitable high yielding varieties for SCI model, exploring and exploiting traditional varieties is one good option. A successful example of Odisha Millets Mission (OMM) included collection of 97 finger millet landraces followed by purification by progeny row selection and participatory varietal selection of nine landraces in 28 blocks of seven districts in farmers' fields. The trials were conducted in a RBD with three replications using microbial organic inoculants such as *ghanajeevamruta* and *jeevaamruta*. Among them, four varieties *viz*., Kalia (P), Bati, Bharati and Mami were higher yielding (>40%) over the state check, Arjun (1098 kg/ha) and Kalua (1218 kg/ha) (Mohanty *et al.,* 2022). Majority of the farmers in seven districts preferred such high yielding landraces or traditional varieties but seed multiplication and availability need to be addressed.

Existing seed systems support only notified and released/registered varieties. The need for an alternative seed system led to discussions on increasing the access of quality seed to farmers specific to each eco-geographic region, mainstreaming landraces based on traditional knowledge, protocols for collection through melas, evaluation, release, conservation and seed supply chain. Alternative seed system exclusive to landraces or traditional varieties as a parallel channel is approved by the Government of Odisha. Such a system considers the farmer fields data recorded in crop cutting experiments; evaluation to release is confined to the specific traditional varieties and crop cultivated niches, community needs and preferences recorded and valued by involving the community representatives from selection to release process. There is a need to develop such a seed system for the varieties that are identified or developed for SCI.

Key Policy needs

Alternate seed systems mainly emerged to increase access of farmer preferred, location and culture specific traditional varieties. Efforts to mainstream traditional varieties that are found suitable to SCI need collaborative efforts between institutions and farmer centric organisations. Collection of location specific traditional varieties through conducting '*Melas*' and their conservation needs joint efforts. Expertise available in institutions may help in guiding phenotyping and conducting participatory varietal trials in farmers' fields. Multi-location trials with an emphasis on altered agronomic practices as per SCI or farmers' practices using organic agriculture will help in identifying suitable varieties.

Protocols for location specific identification and release of traditional varieties were initiated similar to OMM approved process may be developed by formulating state level apex committee including representation of State Agriculture Department, ICAR, OUAT, SSTL, NGOs, custodian farmers etc. Committee will consider promising location specific landraces based on the traits of value to the communities with due importance to performance under SCI in addition to food, nutrition, organoleptic traits, climate resilience, pest and disease resilient and income of the farm families. Apex committee may also set up a Sub-committee from time to time to monitor execution, monitoring and conservation of farmers' varieties. This includes a landraces release sub-committee to develop seed standards, certification protocols, scrutinise applications for release of landraces. Though the effort is on mainstreaming the release of landraces on par with CVRC/SVRC and PPV & FRA, it is imperative to keep the SCI varieties developed from traditional varieties in public domain and there would be no exclusive rights to any individual, organisations or community.

Conclusion

SCI, an emerging system of crop cultivation has potential for crop improvement. As of now there are no specific varieties developed for SCI. Plant types and breeding approaches suitable to SCI specific varieties are discussed with scientific basis. A history of crop improvement success stories indicates unilateral investment and importance to genotype alone ignoring the role of crop management interventions is not balanced either to achieve targeted yield and quality or ensuring the ecosystem health. As SCI is still an emerging field, research and public investment need to focus on selection of genotypes that performs well in specific niches in the changed agronomic packages of SCI. Exploring the potential of traditional varieties adapted well in specific ecological niches can be a way forward. Seed systems may be further strengthened to widen the scope of mainstreaming farmer preferred, location specific, highly adaptive traditional varieties.

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