Review

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Review

Approaches and Advantages of Increased Crop Genetic Diversity in the Fields

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Abstract: Crop genetic diversity is most important for the long-term sustainable production system. The breeding and production strategies of developing and growing uniform and homogenous varieties have created many problems. Such populations are static and very sensitive to unpredictable stresses. In Nepal, more than 80% of seed system is informal which has contributed greatly to creating and maintaining genetic diversity within the field. This paper aims to assess and present the approaches and advantages of increased crop genetic diversity in the fields, based on the experiences of implementing on-farm conservation activities carried out in Nepal since last two decades. Some of the evidences have been derived from on-going evolutionary plant breeding (EPB) project being implemented in Nepal. The information is supplemented with field assessment, focus group discussion, and literature review. The major approaches to increase crop genetic diversity are evolutionary plant breeding, cultivar mixture, landrace enhancement, informal seed system, bulk method, diversifying the seed sources, participatory plant breeding, open pollination, etc. EPB and cultivar mixture are very simple and effective approaches to increase crop genetic diversity at field level. The involvement of farmers in these approaches helps to accelerate the population improvement maintaining the higher degree of genetic diversity. The major advantages of increased crop genetic diversity are: seed maintenance by farmers themselves, minimal risk of crop failure, resilience to unpredictable stresses, increased amount of diversified nutrition, production increment, ease to produce organically, etc. However, there are some issues and problems associated with mixtures and intra-varietal diversity, for example, not being able to harvest by machine, mature at a different date, difficulty in maintaining seeds and registration, etc. Crop genetic diversity should be considered as a sustainable approach for a climate-resilient and self-dependent production system. The higher the genetic diversity in farming land, the more chance of getting the multiple benefits in the agriculture system.

Keywords: evolutionary population; informal seed system; landrace; resilient; varietal mixture

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Introduction

Crop genetic diversity has been created by nature, and managed, utilized and maintained by farmers across the world. Farmers always transfer their crop diversity to the next generations and other farming communities (Fadda 2016, Joshi 2017). Before the green revolution, genetic diversity was very high in the fields. Even in Nepal, where the modern varieties have not been reached, there is higher genetic diversity being maintained by farmers compared to farming areas of modern varieties. It is commonly said by agriculturists, that native landraces perform poorly and could not meet the demands of the human population in the world. As advances were made in agriculture, grain yields of a few crops have been increased significantly, however, crop genetic diversity in the fields goes decreasing (Chateil et al 2013). and some farmers' rights are transferred partly to other institutes. Genetic diversities have been now confined in buildings with static conditions and

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exploited by agricultural researchers, especially by plant breeders for their business. For example, the Consultative Group for International Agricultural Research (CGIAR) has more than 700,000 crop accessions collected from different parts of the countries. CGIAR uses this diversity for developing better genotypes and then transfer them to farming areas. There are many other private and public organizations that are doing similar business.

Crop genetic diversity in the fields is the most important factor for sustainable and secured agriculture. Farmers have realized the demerits of cultivating the uniform and monogenotyped variety in a large area. There are many cases of failure of modern crop varieties. Farmers have many traditional practices that help to maintain and increase the crop genetic diversity in the fields. But these practices are not now in practice in many areas after adopting the modern varieties. Only a few varieties dominate the farming areas e.g. Srijana tomato variety, Mansuli rice variety, etc. in Nepal. This system also replaced many native and localized crop landraces. Realizing the genetic erosion from the fields, some organizations started working on increasing the genetic diversity in the fields and have developed different approaches that also help to conserve genetic diversity in a dynamic state (Gauchan et al 2018, Garland and Curry 2022, Sthapit et al 2019, Wuest et al 2021). These approaches are also good for strengthening agroecological services (Hajjar et al 2008, Sirami et al 2019)) as well as diversifying the produces in household and market.

This paper, therefore, documents the existing approaches and practices to increase genetic diversity in the fields, so that this information could contribute to maintaining, increasing, and utilizing the diversity across the farming areas. An increased understanding of the importance of genetic diversity will further guide the policy and strategy formulation and development (Fu 2015, Govindaraj et al 2015). Information in this paper is based on the past and current experiences of implementing on-farm conservation and evolutionary plant breeding projects being implemented in Nepal in the last two decades and it is supplemented with field assessment along with traditional knowledge and practices, focus group discussion, and literature review. Knowledge gained from the field experiments and interaction with breeders had also been documented. Information was also generated from farmers' field days, national and regional workshops, participatory varietal selection experiments and participatory preferential ranking works carried out over the multilocation and multicrops.

Crop genetic diversity

Crop genetic diversity includes diversity from domesticated species to alleles. Farmers mostly diversify the production domains by using different species, crops, varieties, landraces and trait-specific genotypes. Crop genetic diversity is defined as any variation within and between crop cultivars including their genotypic and phenotypic characters. Crops are domesticated plants used extensively for human benefit and managed by humans in their agricultural systems, e.g. rice, bean, apple, potato, forage species, etc. Cultivars are crop genotypes that are at cultivation practices and it includes both varieties and landraces. Varieties are crop genotypes developed by breeders and cultivated in farming areas. Landraces are traditional genotypes, locally adapted, genetically altered by nature and maintained by farmers over a long period. Diversity can be of different types e.g. intra and inter crop diversity, intra and inter cultivar diversity, intra and inter varietal diversity, intra and inter landrace diversity, etc. Within cultivars, there are two types based on genetic diversity. One is called a monomorphic cultivar which is uniform, homozygotes and morphologically and genetically the same. The other is polymorphic, which is heterozygotes with more than one type or different types of forms at both phenotypic and genotypic levels. The variability in these genetic resources (which is governed by many drivers) can be measured using different approaches at different levels (Bhandari et al 2017). Major drivers of crop genetic diversity are land type, season, market demand, family demand, technology availability, and incentives, etc. Crop genetic diversity has been considered very important for food, nutrition, business, health and environmental security.

Diversity in research and production systems

Agricultural researchers collect diversity both native and exotic including wild relatives from fields and institutes. They also create and maintain diversity through hybridization, mutation, genetic engineering, etc. Much of the diversity has been mostly confined in the buildings, e.g., gene banks or other reservoirs and only a few selective lines have been used for cultivation purposes due to their high production performance, which has resulted the narrow down of crop genetic diversity in the field (Joshi et al 2020a, Joshi 2017). More-importantly, genotypes in research fields have very less interaction with environmental factors in conventional breeding system as most of the research activities are carried out within the research stations. Conversely, participatory plant breeding allows high level of acclimatization of variety with the target environment as most of the research activities are conducted in the farmers' field. In formal cases, the genotypes are mostly handled and exposed to the chemical production system i.e., chemical fertilizers and pesticides. The advancement of genotypes is based on a single trait and targeted to make them homozygotes, and uniform. The various diverse genotypes are discarded and only a few selective genotypes are used in the research fields. This has resulted the loss of allelic diversity from gene pool shared by landraces and other crop cultivars. Thousands of diverse genotypes are discarded each year in the research stations, from where, a very narrow genetic base population and genotypes are then tested in farmers' fields.

In contrast to the research station, diversity is very high in the farmers managed production system. Any genotypes have to interact with many different environmental factors for their adoption as the cultivars have ultimately to be grown in open field conditions. Due to diverse factors in the production fields and households, farmers consider multiple traits. Farmers generally give nature to select the genotypes for next season's planting. The diversity, therefore, is found higher in crops, managed by farmers from seeding to storing seeds by themselves in comparison to crops that are taken from a formal seed system. Phenotypic variability including off-types (of the same crop) have been continuously retained into informal seed systems which help create and maintain genetic diversity. Additionally, in the production system managed through the formal seed system, some farmers' rights have been knowingly or unknowingly transferred to other seed companies, e.g. production and marketing rights of seeds of different classes. In this system, seeds are produced in different locations, other than grain production sites, (may be far from the grain production domain). This may sometimes cause an environmental shock to varieties in the production system.

Approaches for increasing diversity

During the field visit, focal group discussions, and interaction with farmers, several different approaches and methods (Table 1) have been found in farming and research areas to increase the genetic diversity in many different crops. Some approaches are traditional and some are developed by researchers and transferred to farmers. These approaches are practiced by farmers mainly on rice, wheat, maize, bean, oilseed crops, vegetables, finger millet, foxtail millet, barely, proso millet, amaranths, soybean, and other grain legumes. Some approaches look very simple but help greatly to maintain and increase the diversity in the fields. Farmers, growers and researchers who love genetic diversity are followings these approaches and getting benefits. These approaches look highly practicable for the on-farm conservation and restoration of crop biodiversity. Germplasm exchange and repatriation based on climate analog tools are also very effective to get higher production and conservation of diversity in the fields. Multiple approaches might be good to use even in a single landrace for getting higher benefits as well as to accelerate their conservation on-farm (Hufnagel et al 2020, Reinprecht et al 2020).

Table 1. Approaches for increasing crop diversity in the fields.

Scheme	Approach	Explanation and applied crop groups	Remarks
1.	Bulk method	Bulking of seeds from different plants, and/or from different fields, blocks, plots and plants. In cereals and grain legumes.	Some farmers have more than one separate field to grow crops and helps to bulk the seeds from different fields
2.	Bulk seed processing	Crops harvesting together for both seeds and grains from all fields and threshing, cleaning, drying and storing together. In cereals and grain legumes.	No selection and separation of seeds for next season's planting
3.	Classes-bulking selection	Making different classes of crops in the field, selecting within classes, and mixing selected seeds from all classes. In rice, bean	Classes can be made based on the farmer's preferred traits and other important morphological traits, seed color, size, etc.
4.	Community genebank	Many different landraces are made available to the local community. They also conserved the same landraces from different farmers and sites. In cereals, grain legumes, and vegetables.	It also includes a community seed bank and facilitates to exchange seeds, and adds new collections. Mixed seed collection from different farmers helps to increase diversity.
5.	Crossing	Hybridization of two or more different genotypes to get segregating lines. In rice and maize	Segregating lines provide diversity selection option
6.	Cultivar mixture	Growing more than one landrace/ variety together in the same fields. In cereals and grain legumes.	Continue mixing can help generate new genotypes
7.	Multiple sources for seeds	Different seed suppliers can provide many different genotypes of the same crops. Seed sources from the local shop, relatives, neighbors, community seed bank, market, etc. help to increase the diversity. In cereals and vegetables.	Informal seed sources supply broad genetic base materials whereas formal seed sources generally supply uniform varieties.
8.	Diversity block	Many blocks or plots of different cultivars within a field. In cereals	It provides diversity to farmers for selection and helps maintain the diversity within a targeted locality.
9.	Diversity fair	Display of all crops and their seeds/ germplasm by many farmers in one place at a certain time. In cereals, grain legumes and vegetables	All available crop diversity can be seen, exchanged, and traded.
10.	Diversity field school	Farmers and experts discuss and observe crops diversity in the field. In cereals	Similar to farmer's field school, but focus on genetic diversity

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11.	Diversity kit	Planting pack with a mini pack of many different crops' seeds. In cereals, grain legumes and vegetables.	It includes the elite line, released variety, native landraces of many suitable crops
12.	Evolutionary plant breeding	Mixing and growing many more (>10) landraces and varieties together focusing on developing dynamic mixture population by using many segregating or recombinant inbred lines. In rice and bean	Very easy way to conserve crop biodiversity through the uses
13.	Informal seed system	Exchange or marketing of seeds among farmers without any formal regulations. In cereals, grain legumes, vegetables and fruits	The very old system exists in many communities for multiple crop species
14.	Insect-friendly farming system	Ecological agriculture favor insects which help to pollinate and maintain genetic diversity. In maize, oil seed crops, and vegetables	Insect field genebank accelerates the pollination in many crops
15.	Landrace enhancement	Participatory selection of landraces for their genetic improvement. In cereals and grain legumes	Farmers prefer to grow landraces if their genetic performance enhanced
16.	Mass selection	Selection of particular seeds from different plants and mixing them. In cereals and grain legumes	Simple and common practices but effective in large population size
17.	Mix cropping	Growing more than one crop in the same field. In maize, finger millet, pumpkin, cowpea.	Increased diversity at species levels
18.	National Genebank	Collection of all types of crop diversity from around the country and distribution to farming communities. In cereals, grain legumes, vegetables, oil seed crops	Useful to repatriate the landraces as well as to establish diversity blocks in the target location
19.	Negative selection	Removing seeds or plants that are not suitable or cannot produce seeds very well. In vegetables	Selection pressure is very low
20.	Open pollination	Pollination and fertilization go naturally. In cereals, grain legumes, vegetables, oil seed crops	Pollinators help to accelerate the creation of genetic diversity
21.	Participatory plant breeding	Involvement of farmers and breeders in selection and evaluation including hybridization and handling of segregating lines. In rice, wheat, buckwheat	Segregating lines are generally handled in a target environment

 doi:10.20944/preprints202304.0614.v1

22.	Participatory seed exchange	Event of farmers in a certain place to exchange seeds of mainly rare, endangered landraces. In cereals, grain legumes and vegetables	Organize during seeds scarcity i.e., after the earthquake, flooding, etc.
23.	Participatory varietal selection	Growing of few fixed genotypes (generally 5-10) in farmers' fields along with local in farmers' management system. In rice, wheat, maize, grain legumes	Farmers can select more than one variety. Different farmers can select a different variety
24.	Repatriation	Growing of landraces that were available in the past but not now. Additionally, climate analog tool can be used to identify the suitable germplasm to repatriate the climatically smart germplasm. In rice, bean, prosomillet, foxtail millet	Such materials can be collected from National and Global Genebank. Landraces can be collected from climatically analog sites
25.	Multiline variety	Growing more than one different line. In rice and bean	Usually, these are breeding lines and differ from each other for certain traits
26.	Near isogenic lines	Lines that are genetically identical except for the allele at one locus. In rice	Applicable to mostly for monogenic traits
27.	Site-specific variety	Development and maintenance of variety for a particular site. In cereals and grain legumes	A large number of different varieties are needed for diverse agroecosystem
28.	Growing the same variety over a time	Growing the same variety over a period in the same field by different generations. In cereals, grain legumes, oil seed crops	Selection choices and mutation along with natural crossing create and maintain diversity
29.	Hybrid swarm	Cultivated varieties may cross with wild relatives available near to field and grow their progeny in the field. In rice and wild rice	It is common in rice that crosses with wild rice available near the field. Many different genotypes can be observed in next generation
30.	Shattered seeds and off-types in the next season's plant population	During harvest in some crops, seeds fall in the field and grow together the next season with a seeded plant population. Off types are also included in the farming system. In rice, wheat, finger millet	These favors growing both in-situ and on-farm materials together
31.	Manual weeding during flowering and multiple harvests	Manual weeding during flowering helps to pollinate the flowers by shaking plants. Similarly, during picking fruits, seeds in indeterminant plants may shake plants to pollinate. In maize, oil seed crops	Weeding and traveling during flowering accelerates the cross-pollination
32.	Natural selection	Growing landraces with minimum human interferences	No selection during harvest and seed cleaning

		and survival of the fittest are applied. In cereals and grain legumes	
33.	Parent-offspring mix plantation	Growing parental lines and their offspring together in the same field. In finger millet, sponge gourd, cucumber	Farmers sometimes mix newly harvested seeds with the previous year's seeds
34.	Ethnicity specific variety	Ethnic groups need different crops and landraces for their cultural and religious purposes. Based on their requirements, variety is developed and grown. In cereals	Diverse ethnic groups live together and may have different genotypes
35.	Natural agents for translocating planting materials	Sometimes, natural factors/ agents, e.g., birds, insects, wind, and flood transfer seeds and other planting materials from one location to another. In wild rice, amaranth, prosomillet	New genotypes can be observed in the fields and harvested together with normal plants

Note: This table is based on the experiences of farmers, authors, and a brief interview with agrobiodiversity-rich farmers and researchers.

For increasing diversity, farmers' practices are relatively better than modern agricultural practices. During creating diversity in the fields, different multiple traits should be considered for the selection of genotypes. Trait-based selection for mixing landraces and varieties depends on the biotic and abiotic stresses (Table 2). For example, different root-length cultivars are suitable for cultivation in drought areas. However, maturity and cooking methods should be the same for all mixed landraces and varieties. In the case of the in-determinant type, maturity is not applicable to consider.

Table 2. Important traits for mixing cultivars (landraces and varieties) against different conditions.

For space use (all dimensions)	For disease and insect pests	For drought	Similarity in traits
• Different root lengths and texture • Different plant height • Different plant structures, and shape • Different sizes and canopy	• Different reaction capacities with insect pests and diseases • Different leaf and stem texture • Different colors and sizes • A different scent, and secondary metabolites	• Deep root • Erect plant/leaf • Different plant heights and canopy • Large leaf but few	• Maturity • Cooking method and time • Milling

Advantages of increased crop diversity

Increased diversity in the field ensures the harvest and minimizes the risk of crop failure due to both biotic and abiotic factors (Begna and Begna 2021, Joshi et al 2020d). The crop diversity will contribute to yield stability and insect and pest resistance/tolerance due to broad genetic base derived from diverse germplasm sources (Furman et al 2021, He et al 2021). A few advantages associated with high intra-varietal diversity are given in Figure 1. Jumli Marshi (Figure 1 left) is highly polymorphic and as a result we have observed less disease pressure as well as low vulnerability to climate related abiotic stresses. Due to climatic variations and requirements of different products to meet the preference of clients, the majority of farmers in Nepal grow a large number of crop species and their varieties as well as landraces. Growing varieties of the same crops are easy as well as provides multiple benefits. It is very important for sustainable agricultural business maintaining a functional agroecosystem. Many farmers are well familiar with the advantages of increased crop diversity in the fields. In many areas, we observed that farmers grow different crop species together as well as mixed populations of varieties and landraces (Figure 3). Some practices of farmers are given in Table 3 along with advantages. Farmers keep seeds from such mixed populations for next season which favors natural selection. Alongside, they are resilient to climate and other environmental factors (Lin 2011) including weeds (Pakeman et al 2020) and perform relatively better than other newly developed narrow genetic base varieties.

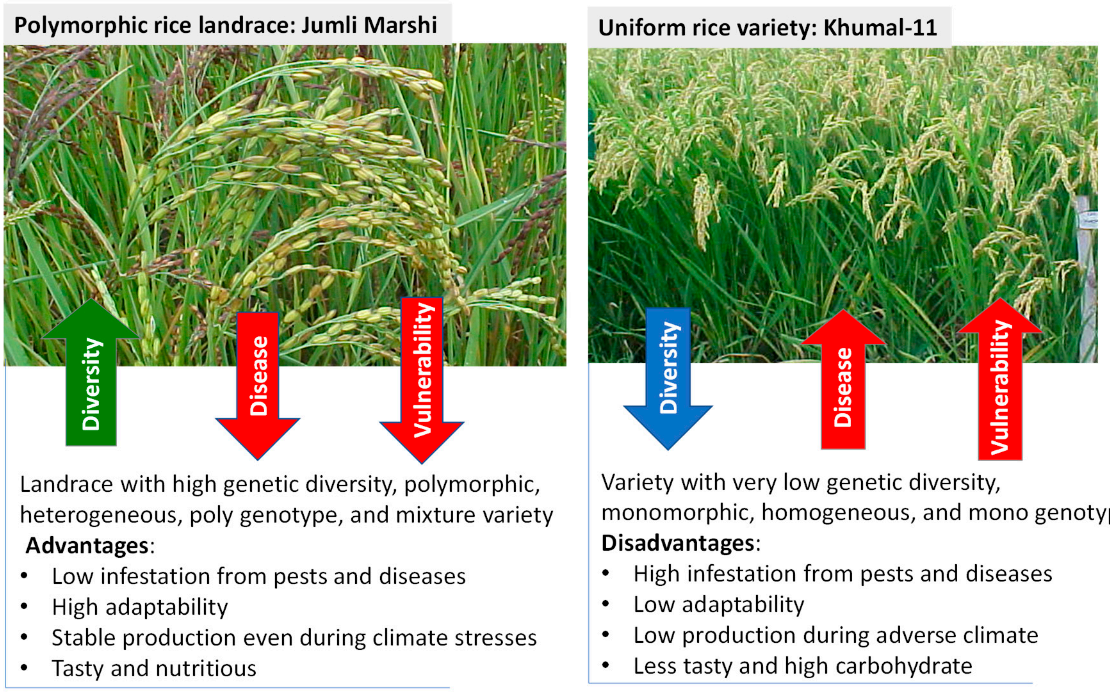

Figure 1. Advantages and disadvantages of polymorphic and uniform cultivars. Arrow indicates either increasing (up arrow) or decreasing (down arrow) for a trait included in the arrow box.

Table 3. Farmers' practices of mixing landraces and varieties of bean, finger millet and rice in Nepal.

Crop	Mixing components	Site	Advantages
Bean	>20 landraces	Jumla	Less damage by diseases (anthracnose, rust, leaf spot, blight, etc.), 2-3 months continuous harvest, tasty
Finger millet	Dalle Kodo + Bhotyangre Kodo + Chyalthe Kodo	Jugu, Dolakha	High yield, good forage, fewer diseases (blast, smut, blight)
Rice	Kali Marshi + Chandanath-1 + Chandanath-2	Jumla	Less damage by blast, taste remains as local landrace
Rice	Gurdi + Mansara	Pame, Kaski	Better even in drought condition, less damage by insect pests and diseases
Rice	Kalo Patle + Machhapuchhre-3 + Lekali	Dhikur Pokhari, Kaski	No damage by a monkey, higher grain yield, less damage by disease, no lodging
Rice	1. Mana Muri + Sano Gurdhi, 2. Kathe Dhan + Panhele, 3. Thimaha + Anga + Mansara,4. Kalo Patle + Chommrong + Machhpuchhre-3	Kaski	Lodging tolerant, less damage by insect pests and diseases, testy, high grain yield

Source: Joshi et al., 2020.

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The figure depicts traditional farmers practices of growing mixtures of crops on the same piece of land (Figure 2A) such as rice, foxtail millet and Brinjal (eggplant or aubergine), mixed cropping of maize, pumpkin, and beans in east Nepal (Figure 2B), seeds harvested from diverse beans in Jumla and Rukum districts of Nepal (Figure 2C) and an a mixture of rice composed of over 50 landraces grown on the same plot (Figure 2D).Mixtures are planted deliberately to avoid complete failure of farms in case of occurrence of biotic and abiotic stresses (Figure 1; Table 3).

Figure 2. Genetic diversity in the field, A. Crops mixture (rice + foxtail millet + brinjal and others) in Humla district, B. Three sister crops (maize, pumpkin and bean) in East Nepal, C. Two bean landraces in Jumla and Rukum districts, D. Evolutionary rice population in Jumla district (50 rice landraces).

Practices for narrowing the diversity

The farmers' traditional knowledge and practices favor creating and maintaining both intra and inter-varietal diversity. But as the advances made in agriculture, many practices are towards narrowing the genetic diversity. For examples, plant breeders test and evaluate only the selective genotypes in many locations and countries. Genotypes that perform well in multiple sites are promoted and integrated into the formal seed system (Joshi et al 2020b). The promotion of stable genotypes based on genotype by environmental interaction across the world leads to narrowing the genetic diversity in the fields. The CGIAR-based materials are tested in the similar fashion. This system also includes a collection of diversity as much as possible from the fields and stores in the buildings and then expands a few high-yielding varieties (uniform and monogenotype) in many areas. Recommendation of a single variety to a large area in many countries drastically replaces the many site-specific crop landraces.

In many breeding institutes, a single breeder leads the breeding works and a narrow perspective dominates the breeding process. The majority of breeding works is to focus on a single trait i.e., grain yield. Both single-led breeding work and single trait-based breeding programs could not broaden the genetic base across the locations (Fu 2015). Research and development in these institutes are also focused only on few selected crops. Due to this, geographical coverages of few crops are increasing and resulting in the cultivation of narrow diversity at species and varietal levels. The dissemination method of newly developed varieties along with incentives also promotes the narrow genetic base varieties. Farmer field trials (FFT) and minikit are very common methods adopted by many countries to disseminate the varieties. The expansion of growing F1 hybrid and genetically engineered varieties are very high. All of these varieties are almost non-evolutionary and therefore could not maintain genetic diversity in the field. Other breeding methods, e.g., pure line selection, pedigree methods, backcross, etc. also develop very narrow genetic base varieties.

Sources of planting materials are dominated by a few companies. Covering large areas by a single source of seed supplier leads to genetic erosion from the fields. In fruit species, the use of same rootstock for large number of varieties as well as clonal propagation have also drastically reduced and narrowed down the diversity. Similarly, mechanization is another practice that triggers to grow uniform varieties. Many breeding works also target to develop homogenous varieties so that mechanized farming could be possible. The policy also favors uniform and distinct varieties. The system of the distinctness, uniformity and stability (DUS) test promotes homozygotes varieties rather than increasing the diversity in the fields.

Impact of narrow genetic diversity

Narrow genetic diversity is mainly due to the replacement of landraces by modern variety. Modern variety has very low intra-varietal diversity compared to landraces (Joshi et al 2018). Selection response in such narrow genetic diversity is almost negligible. Because of the lack of buffering capacity, these varieties are vulnerable to both biotic and abiotic stresses (Lin 2011, Reinprecht et al 2020) and there are many cases of complete failure of production in many crops. Insect pollinators prefer to visit fields where diversity is high both at intra and inter-varietal levels. In addition, ecological services from such a narrow genetic base are very poor. The very specific parts (i.e., above and below ground) have been exploited all the time if grown same narrow genetic base varieties over time. If farmers keep seeds for the next generation themselves, the performance may reduce, and therefore, the formal system target to increase the seed replacement rate each year. This also indicates the detachment of farmers' rights from their old age rights.

The environment, growing conditions, and everything keep changing. In the production system. Many different types of living organisms get connected due to which agroecosystem and soil remain balanced and functional. The narrow genetic varieties are not evolutionary and natural selection does not work. Nutritionally, the products from such varieties are high in carbohydrates and low in other important nutrients compared to landraces (Joshi et al et al 2020b). The narrowing of crop genetic diversity also limits plant breeding (Swarup et al 2021); genetic advancement such as marker assisted selection (Mengistu et al 2016) and disease resistance enhancement in crops (Hinge et al 2021).

Policy dimension

In Nepal, there are three types of seed systems, namely formal, informal and non-formal. The formal system handles released and registered varieties under National Seed Board. An informal seed system ensures the exchange and transfer of very diverse and heterozygotic landraces generation after generation, which means, it is a carrier of genetic diversity. However, for integration of any variety into a formal system, it should be uniform and homozygotes as per the existing seed regulation, which highly discourage cultivar mixture and landrace diversity. A formal seed system is utmost for the commercial production and marketing of any crop varieties and landraces. Any type of genetic variation at species and varietal levels is not favored by the existing seed policy. Incentives are also not provided for non-registered landraces and cultivar mixtures. In the formal seed system, farmers are mostly excluded to multiply seeds of some seed classes, e.g. breeder seed, and foundation seed due to requirement of formal university degree and well managed seed processing infrastructures. This also discourage the farmers to continuously engage in seed sectors especially for maintaining on-farm diversity. This is also a situation detaching farmers' rights from farmers and increasing the dependency on other agencies for seeds. There is also a debate on treating landraces either as public or private goods for farmers, but many private companies and institutes handle varieties as private goods. Still, many farmers have very unique landraces with high genetic variation; therefore, policy should favor to promote and maintain genetic variation at field level, as well as landraces should be considered as private goods.

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Conclusion

Genetic diversity in the fields is decreasing since the Green Revolution. Crop diversity is stored statically in confined areas called Genebank whereas uniform and homozygotic varieties are increasingly covering the farming areas. Globalizing the crop genetic resources and then favoring widely adapted varieties across the world resulted in a very narrow genetic base in formally developed crop varieties. Genetic diversity is most for securing crop harvest even under adverse climatic and biotic stresses. Many farmers and agriculturists have now increasingly realized the necessity of maintaining genetic diversity in the fields. Many different approaches have been therefore developed, restarted and applied in major crop species e.g., rice, wheat, barley, bean, finger millet, etc. As the diversity increased in the fields, their evolutionary rate also enhanced from where better genotypes could be appeared and selected for the next generation. Some approaches are also very effective to help farmers for saving seeds from their own field for next season planting. Ecological and evolutionary approaches should be considered worldwide for every crop species to increase the diversity in the fields.

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