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Benefits and Costs of Growing Dynamic Mixtures

Evidence from Nepal: Rice and Common Bean

MARCH 2023

Introduction

Conventional crop breeding faces several limitations that hinder its ability to meet the needs of farmers and the wider food system, including costs of varietal development, and a focus on certain crops and varieties with broad market potential, while potentially under-emphasizing varieties most preferred by farmers or consumers (Westengen et al., 2023). Evolutionary plant breeding (EPB) has emerged as an alternative approach that integrates the knowledge and priorities of farmers and other stakeholders to identify niche-specific broad genetic-base varieties (Joshi et al., 2023). EPB is a decentralized and participatory method, with farmers and researchers collaborating to facilitate the development of crop varieties that are better adapted to local environmental conditions and meet the preferences of end-users (Döring et al., 2011; Joshi et al., 2020).

Cultivar mixtures are obtained by mixing the seeds of a number of cultivars for planting (Ceccarelli and Grando, 2020), while Evolutionary Populations (EPs) are developed by mixing seed produced from crosses between many varieties (Raggi et al., 2017; Ceccarelli, 2009). Mixtures are easier to produce in the absence of facilities and expertise needed to develop suitable crosses. Mixtures can be static or dynamic. Static mixtures are made up by mixing the seed of each of the components at the beginning of each cropping season. When part of the grain produced from such mixtures is used as seed for the following crops, the capturing effects of natural selection would be enhanced and mixture become dynamic (Ceccarelli and Grando, 2022). Both mixtures and EPs integrate the knowledge, experience, and goals of farmers, allowing for the development of locally adapted varieties that are better suited to changing environmental conditions (Neupane et al., 2023).

Though cultivar mixtures and EPs both represent promising approaches for resilient food systems, farmers may face several challenges related to the management of planting materials (Wuest et al., 2021). Hence, there is a need to develop metrics for assessing performance of varieties developed through EPB to optimize these approaches and facilitate wider adoption.

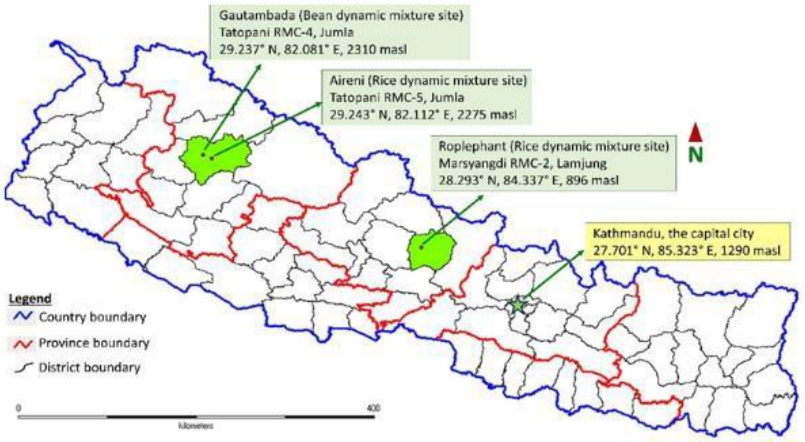
The non-governmental organization, Local Initiatives for Biodiversity, Research and Development (LI-BIRD) and the National Genebank of Nepal Agricultural Research Council (NARC) have implemented the Evolutionary Plant Breeding (EPB) project in two locations in Nepal - Lamjung and Jumla Districts (Figure 1) from July 2018 to March 2023, with an aim to support resilience to climate change, sustainable crop productivity, and improved nutrition under rainfed conditions with a focus on poor and smallholder farmers. The specific objective of the project was to develop stable and high-yielding mixtures from germplasm comprised of landraces, improved varieties and breeding lines for rice and bean by conducting on-farm trials

This paper presents the finding of a 2021 survey of 67 farm households, with a focus on perceived benefits and challenges of cultivating mixtures in rural Nepal. We further explored the possibility of mainstreaming cultivar mixture into national research and extension systems.

KEY FINDINGS

- Mixtures and Evolutionary Populations (EPs) have the potential to support climatic adaptation while sustaining yield and providing nutritional benefits.
- Farmers from Lamjung and Jumla districts in Nepal reported cost reductions in rice and bean cultivation using dynamic mixtures.
- Dynamic mixtures can reduce costs of weeding, spraying, fertilizer / manure, and irrigation.
- The inter-varietal diversity within mixtures allows some lines to resist pests, diseases, drought, and limited water availability, thereby reducing costs from external inputs and associated labor costs.
- Farmers reported higher satisfaction from dynamic mixtures in the study sites, indicating their potential for wider adoption in the farming practices of Nepal.

Figure 1: Study sites for the EPB project in Nepal.



Dynamic Mixture and Evolutionary Populations (EPs) are potentially climate resilient agricultural practices. Both will be effective for sustainably increasing yield with minimal external inputs.

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This study was undertaken by LI-BIRD, NARC and Alliance of Bioversity International and CIAT with funding support from IFAD under the EPB project.

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Farm and household characteristics

Data collection included household surveys in October- November, 2021 to assess perceived benefits and costs of cultivating mixtures for rice (*O.sativa*) and common bean (*P. vugaris* F.) in two districts of Nepal. The survey involved 67 purposively selected farm households in Lamjung district (n=23 rice producing households) and Jumla district (n=44 rice and bean producing households).

The average age of survey respondents in both Lamjung and Jumla was 44 years. Educational attainment was significantly lower than the national average, with over half of survey respondents being illiterate. In total, 66% of survey households were female-headed in Lamjung and in Jumla female-headed households comprised 58% (for bean) and 69% (for rice). There was a relatively larger family workforce available for some farms: households in Jumla on average had 5.4 members versus 5.2 in Lamjung, but in Lamjung had relatively more adults (age 16+).

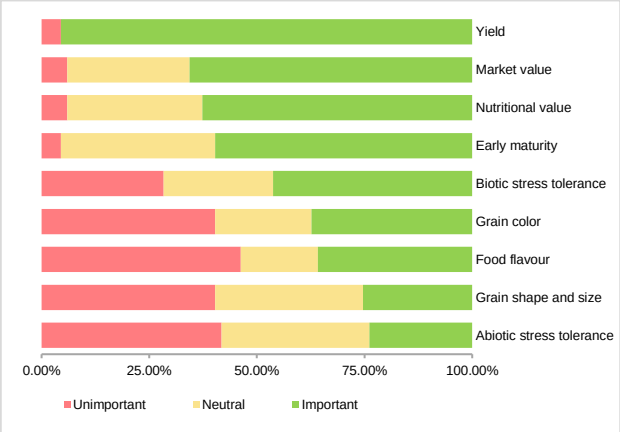
The farmers in the sample households had extensive farming experience, ranging from 7 to 57 years, though all had only 1-2 years' experience growing mixtures. Farm sizes varied from one ropani (508.74 square metres) to more than 10 ropani of land, with a mean of 6.8 ropani in Jumla and 9.7 ropani in Lamjung. On average households farmed 8 different plots, with many cultivating small plots less than a ropani in size. The mean land area allocated to mixtures in the study site was 0.59 ropani per household. The prevalence of small-scale farmers and regional differences in landholding suggest the importance of context-specific policies and programs tailored to the needs of different communities. The preponderance of small parcels also highlights the critical issue of land fragmentation, which may have significant implications for agricultural productivity, efficiency, and land-use planning in the study area.

Most of the households in the study area were predominantly engaged in non-commercial farming, with a focus on cultivating traditional crop varieties. This may suggest a preference for crop varieties that have been locally selected and grown over generations, rather than modern varieties, or it may suggest a lack of access to modern varieties through local market channels. We also note that the use of certified seeds of crop varieties was very uncommon among the sampled farmers, with most farmers reporting use of their own seed or seed sourced freely from local sources. This may present an opportunity to promote mixtures for rice and/or common bean that have been formed and adapted to local environmental conditions and have greater genetic diversity as well as locally-preferred traits.

Farmer priorities for varietal selection

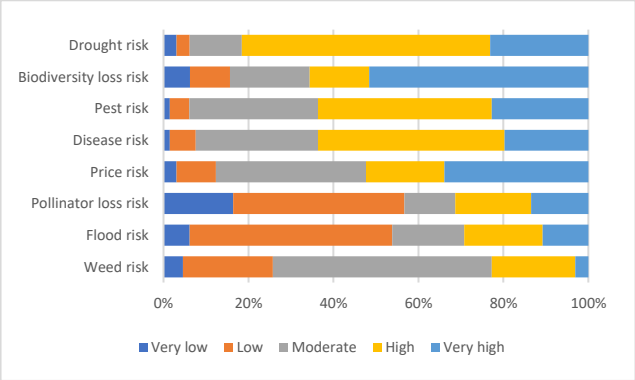
Understanding farmers' preferences for crop varieties is crucial for developing and supporting sustainable and resilient agricultural practices. Survey respondents were asked to rate the importance of different crop traits in their selection of pure line varieties or mixtures to cultivate. Results revealed that the most important criteria for varietal selection were grain yield, followed by market value and nutritional value (Figure 2).

Figure 2: Farmer priorities for varietal selection.



Farmers also rated biotic stress tolerance, grain shape and size, and food flavor as additional important criteria. These responses highlight the importance of prioritizing crop breeding efforts for traits that are critical for farmers' livelihoods in Nepal, such as high grain yield and market value. However, it is also important to note that farmers do not appear to consider abiotic stress tolerance as a primary criterion for varietal selection – and yet abiotic stresses including drought and flooding associated with climate change may lead to significant yield losses. Indeed, in further survey questions assessing farmers' perceptions of risks, drought was perceived as the greatest risk by farmers, followed by loss of biodiversity, pests and diseases, and price uncertainty (Figure 3).

Figure 3: Farmer perceptions of risks to crop production.

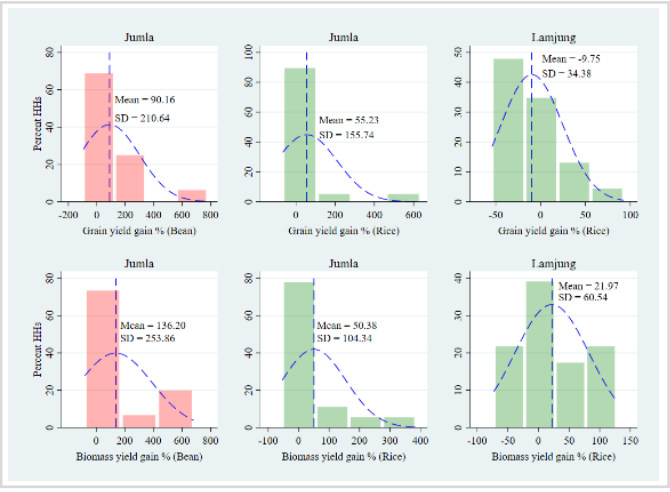


Use of mixtures and EPs has the potential to support development and dissemination of heterogenous genotypes that are better adapted to local environmental conditions, including abiotic stress tolerance, while meeting farmers' primary crop varietal selection criteria around yield and nutritional value.

Productivity impacts of mixtures in the study sites

In the survey households, mixtures of common bean and rice showed normal distribution of yield gain data (both for grain yield and biomass yield) with relatively higher average yield gain compared to pure stand varieties grown by farmers in similar conditions (Figure 4). However, in case of Lamjung, we observed slightly negative yield gain compared to average gain value.

Figure 4: Distribution of yield gain with mixtures compared to the traditional varieties in the study site.



Mixtures of common bean showed slightly higher grain yield productivity than pure stand varieties, with average productivity 2.37 ton/ha compared to 2.33 ton/ha. Similarly, mixtures had higher biomass productivity with 2.99 ton/ha, compared to 2.46 ton/ha for traditional bean varieties.

For rice, mixtures outperformed traditional varieties in terms of grain yield and biomass productivity in both Jumla and Lamjung districts. The grain productivity of mixtures of rice was 5.04 ton/ha in Jumla and 3.85 ton/ha in Lamjung compared to 4.12 ton/ha and 2.59 ton/ha for pure stand rice varieties in these communities. The biomass productivity of mixtures of rice varieties was 7.41 ton/ha in Jumla and 3.79 ton/ha in Lamjung, compared to 5.75 ton/ha and 3.40 ton/ha, respectively for pure stand rice varieties.

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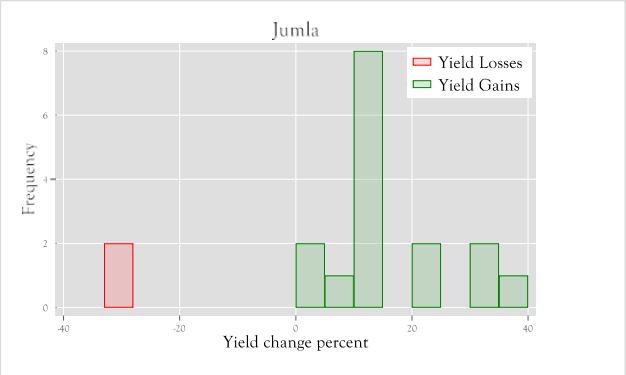
Notably, overall rice grain productivity in the sampled farms was higher (Jumla: 5.04 ton/ha, Lamjung: 3.85 ton/ha) than the national average yield reported for Nepal in 2021, which was 3.82 ton/ha nationally, 2.14 ton/ha in Jumla, and 3.37 ton/ha in Lamjung.

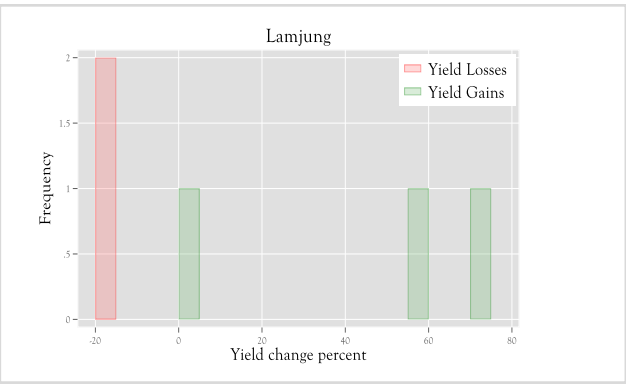
In Jumla, 28% of the respondents reported that the grain yield was unchanged while growing mixtures compared to pure stand varieties (Figure 5a). However, majority of the respondents (64%) reported yield increased up to 40% while growing mixtures. Conversely, 8% of the HHs reported yield loss up to 30% while growing mixtures.

Figure 5a: Yield changes associated with mixtures of rice (Jumla).



Similarly, in Lamjung, 77% of the survey HHs reported that yield was unchanged from mixtures compared to pure stand varieties (Figure 5b). However, 14% of the HHs reported yield increased from 5% to 75%. Conversely, 9% of the HHs reported yield loss up to 20% while growing evolutionary population in their field.

Figure 5b: Yield changes associated with mixtures of rice (Lamjung).



The study results revealed that mixtures were associated with increased yield gain particularly for beans and rice in Jumla though having negligibly negative yield gain value for rice in Lamjung. However, we found higher biomass productivity in both districts compared to pure stand varieties. Overall, these findings suggest that mixtures have the potential to increase productivity in terms of both grain yield and biomass yield while growing them in niche environments specifically for Jumla and Lamjung districts.

Farmers' experiences of growing mixtures vs. traditional varieties

Mixtures are produced not only to improve productivity but also to achieve other potential benefits related to sustainable crop production. In response to open-ended questions about their experiences of growing mixtures, farmers cited several advantages over pure stand varieties including potential for higher production, lower weed infestation, and better taste.

In further crop-specific questions farmers stated that they preferred mixtures of beans over pure line varieties due to their ability to provide satisfactory production at a lower cost, lower weed infestation, and better taste. Similarly, rice growers cited higher grain production, better taste, and higher biomass production as the top reasons for preferring mixtures. These findings suggest that farmers are not solely focused on maximizing yield but also place substantial value on other factors such as taste, weed control, and cost-effectiveness. These results highlight the importance of developing mixtures that can offer a combination of yield and quality traits to meet the demands of farmers in the study area. By doing so, researchers can help farmers to achieve their production objectives while at the same time meet their quality and taste requirements.

Benefits and costs of growing dynamic mixtures

As shown in Table 1, mixtures were associated either with increased costs or decreased costs to farmers for field level cultivation. Farmers reported increased costs of harvesting and threshing with the use of mixtures, but cost reductions was reported in weeding, fertilizer/manure application, chemical spraying and irrigation. These patterns were consistent with previous studies showing the inter-varietal diversity within mixtures allows some lines to resist pests and diseases, enhance nutrient use efficiency, and better withstand drought, thereby reducing the inputs and labor required (Joshi et al., 2023; Raggi et al., 2017; Ceccarelli, 2009). Due to varied growth agro-morphology of mixtures, they may require specialized harvesting and threshing method which subsequently leads to increase costs in these operations.

Table 1: Comparison of input costs between mixtures and pure stand varieties

Farming Operations	Cost difference (%) with mixtures vs. pure stand varieties		
	Rice		Bean
	Lamjung	Jumla	Jumla
Land preparation	0 (0)	0 (0)	0 (0)
Planting	0 (0)	0 (0)	0 (0)
Weeding	-11.98 (13.29)	-10.78 (9.02)	-12.57 (12.37)
Fertilizer / manure	-5.43 (4.48)	-5.82 (4.15)	-6.32 (3.73)
Spraying	-3.74 (4.50)	-8.36 (5.19)	-8.79 (5.48)
Irrigation	-3.48 (3.45)	-4.05 (3.23)	-4.47 (2.50)
Harvesting	4.22 (3.12)	4.45 (3.16)	4.95 (3.26)
Threshing	4.35 (2.84)	3.68 (2.80)	3.84 (2.83)

Values in parenthesis represent standard deviations

It is important to assess the cost-effectiveness of mixtures on a case-by-case basis to determine whether the potential benefits outweigh the potential costs. In Lamjung for example the cost reductions for spraying and irrigation associated with the adoption of mixtures were modest, though these benefits were greater in Jumla, and especially for mixtures of beans.

Therefore, it is important to recognize that the cost implications of adopting mixtures can vary depending on several factors, including the specific crop, cultivation practices, and local environmental and economic conditions. Nonetheless, the cost reduction associated with mixtures is still beneficial, and farmers may also consider long-term benefits of using mixtures, such as adaptation to changing environmental conditions, improved crop resilience to biotic and abiotic stresses, and sustainable crop productivity (Wuest et al., 2021).

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Challenges associated with mixtures

Among 67 respondent farmers, only 25 farmers (37.31%) reported the problems associated with cultivating mixtures of rice and beans, with higher pest infestations (n=16) and lower production (n=9) being the most commonly referred challenges for both the crops. Early maturing lines were particularly susceptible to these issues. For beans, unsynchronized maturity (n=2) and higher pest infestation (n=2) were reported as top concerns, while for rice, mice problems (n=5), unsynchronized maturity (n=4), and difficulty in threshing of mixtures (n=3) were the major identified problems. While these issues were not extensively reported, they can still have a significant impact on crop yield and quality, highlighting the need for effective management strategies.

Implications of the findings

This study highlights the importance of considering farmers' perceptions of risks and their experiences with different crop varieties as well as mixtures and EPs when developing strategies to promote sustainable agriculture. Farmers in the study sites in Lamjung and Jumla districts perceived drought as the most significant risk they face, followed by biodiversity loss, pest and disease, and price instability. Weed infestation, flood, and loss of pollinators were also perceived as significant risks, though by a smaller subset of farmers. To address these risks, the adoption of mixtures may provide effective solutions that can enhance the resilience of agricultural systems and support farmers' livelihoods. Mixtures can support the evolution of new crop varieties that are better adapted to local environmental conditions, improving drought tolerance and lowering risks of pest and disease outbreaks. Similarly, mixtures can promote ecological diversity and thereby mitigate impacts of environmental shocks, weed infestation, and other anticipated challenges associated with climate change.

The farmers in the study area showed that they have placed significant importance on maintaining local crop diversity. Their emphasis on traditional varieties indicates a preference for crop varieties that have been selected and adapted over generations, rather than modern varieties that developed in the formal seed sector with a priority for productivity objectives. Farmers' preferences for traditional crop varieties may also indicate market potential for mixtures, as most of the mixtures used in this study incorporate traditional varieties as a component line for local adaptability.

The findings of this study provide important insights about the potential of mixtures for supporting sustainable agricultural production in Nepal. The findings also highlighted the need to consider perceived benefits and costs (Table 2) when developing and disseminating cultivar mixtures. The preference of farmers for growing mixtures coupled with net reductions in the cost of production, signals strong potential that mixtures could play an important role in enhancing the long-term sustainability of small-scale farm household agricultural production systems.

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Table 2. Summary of perceived benefits and costs of growing dynamic mixtures for rice and beans in Nepal.

Overall Perceived Benefits	Overall Perceived Costs
• Farmers have reported that mixtures can reduce costs in weeding, spraying chemicals, fertilizer/manure application, and irrigation due to their improved pest and disease resistance, better nutrient uptake efficiency, and water use efficiency. • Dynamic mixtures exhibit greater adaptability to local environmental conditions, including heat and limited water availability, resulting in sustainable yield and nutritional benefits. • Dynamic mixtures offer qualitative benefits, such as higher nutritional value, taste, and cooking properties. • Dynamic mixtures provide higher levels of genetic diversity and flexibility, leading to a more resilient agricultural system and mitigating the risks associated with monoculture. • Dynamic mixtures can be grown with minimum external inputs, such as chemical fertilizers and pesticides, thereby promoting sustainable farming practices and reducing environmental impacts. • Dynamic mixtures contribute to the conservation of genetic resources and cultural heritage by preserving traditional crop varieties and promoting the development of new varieties.	• Farmers have reported that harvesting and threshing cost will be increased while using mixtures due to the varied growth habits and physical characteristics of these crops, which may require more specialized methods for harvesting and threshing. • Farmers did not perceive any cost reduction in land preparation and planting while shifting from pure stand varieties to mixtures. • The cost reductions in weeding, fertilizer/manure application, spraying chemicals, and irrigation were reported by farmers, but these benefits were marginal, and the cost savings were offset by the increased costs in harvesting and threshing. • The cost implications of adopting dynamic mixtures can vary depending on several factors, including the specific crop, cultivation practices used, and local environmental and economic conditions. Therefore, it is crucial to assess the cost-effectiveness of using mixtures on a case-by-case basis to determine whether the potential benefits outweigh the potential costs.

Funding Disclosure: The Evolutionary Plant Breeding (EPB) Project in Nepal was undertaken by LI-BIRD, NARC and Alliance of Bioversity International and CIAT with funding support from the International Fund for Agricultural Development (IFAD) project number 2000001629.