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Productivity of Mixtures and Evolutionary Populations of wheat, barley, beans and Rice

Findings from Ethiopia, Iran, Jordan, Nepal and Uganda

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Introduction

Mixtures of different varieties of barley (*Hordeum vulgare*), wheat (*Triticum ssp.*) are grown by farmers in Ethiopia, Iran, Jordan, as a means of diversifying production and/or coping with difficult or uncertain growing conditions. Similarly, mixtures of different varieties of beans (*Phaseolus vulgaris*) were grown by farmers in Bhutan, Nepal and Uganda, with mixtures of Rice (*Oryza sativa*) were also grown by Bhutan and Nepal farmers. The mixture of all crops in all countries were grown for three consecutive years under IFAD – EPB project. Varietal diversity can improve farmers' productivity, capabilities to manage pests and diseases and allows farmers to select suitable cultivars in response to varied or uncertain climatic conditions. Moreover, varietal diversification can improve the nutritional security of smallholder farmers. The availability of crop intra-varietal diversity genetically diverse crop varieties thus has implications for crop productivity and smallholders' food security and livelihoods (Di Falco et al., 2007; Gotor et al., 2021).

On-farm trials of evolutionary plant breeding has been conducted since 2018 as collaborative project between the Alliance of Bioversity International – CIAT and national partners of the six countries with financial support from IFAD (International fund for Agricultural Development). The trials were conducted at 41 localities on 90 evolutionary populations and 60 pure stand varieties of the four crops.

Farm Characteristics

The beneficiary farm households in all the six countries characterized as small scale where crop production is the main means of their livelihood strategy. Most of the farms are subject to climate change impacts such as drought, pest and diseases, grow few varieties of the target crops as well as undergone genetic erosions following the introduction of genetically narrow improved varieties from national as well as international breeding institutions. These characteristics of the farms were common across partner countries.

The trials were conducted to i) Enhance the resilience of target low-input poor farmers in the project area through developing EP populations with higher and stable yields under the local farm agronomic and stress conditions and ii) Improve the farm productivity and household nutritional security though on-farm intra-varietal diversification of major crops.

Study countries and locations

The studies have been conducted in six countries (Bhutan, Ethiopia, Iran, Jordan, Nepal and Uganda) at about 41 locations from 2019 to 2021. About 90 evolutionary populations together with 60 pure stand varieties of barley, beans, wheat and rice were tested at these 41 sites.

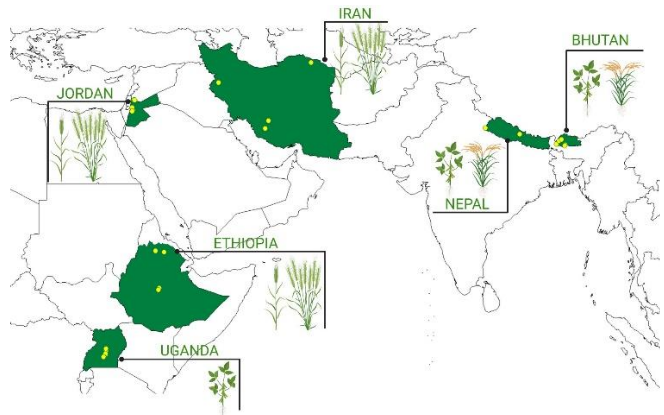

Figure 1. Evolutionary plant breeding countries and locations map

Key results

The analysis done so far demonstrated that most of the mixtures have shown better performance compared to the pure stand varieties for economic traits such as grain yield (GY) and biomass yield (BY) for all crops across test countries, except for Bhutan where the populations were small compared with the pure stand varieties.

Ethiopia: barley population did not show significant difference in GY but slightly higher BY compared to the pure stand varieties. However, wheat populations have displayed improved performance to the pure stand improved varieties. In top 10 high yielding list, 80% and 90% for GY and BY were populations, respectively. Eight (27.6%) of the 27 populations have given as high yield as the best improved variety, Asassa (Fig.2). Moreover, three (11.1%) of the tested population have produced higher average BY than the best improved variety, Asassa (Figure 3).

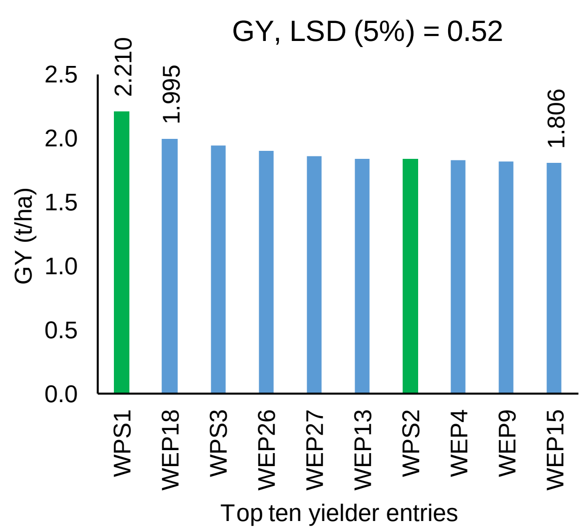

Figure 2. GY of top 10 wheat entries of EPB trial, Ethiopia

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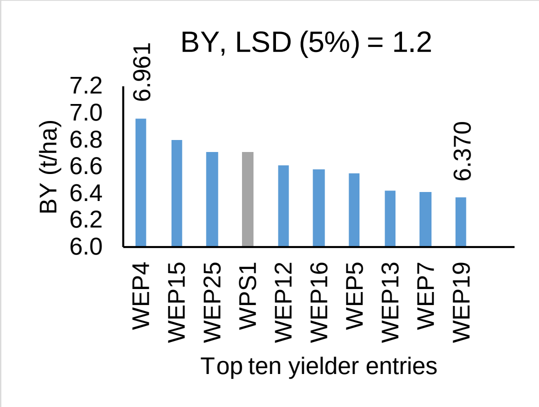

Figure 2. GY of top 10 wheat entries of EPB trial, Ethiopia

Iran: For instance, the best performer barley population in Iran has resulted in GY gain of up to 19.9% compared to the high yield pure stand variety.

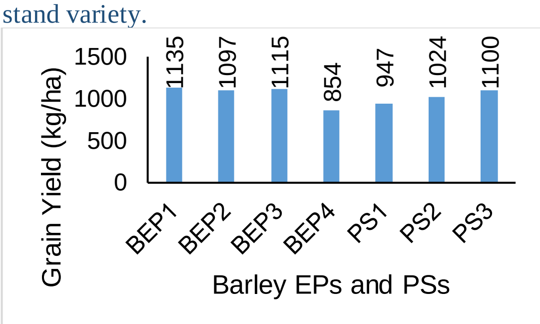

Figure 4. Average GY of Populations (BEP1 – BEP4) and Pure stands (PS1 – PS3) of barley in Iran.

Similarly, Wheat evolutionary populations were found more productive than the pure stand varieties. For instance, all EPs and local landraces tested in various localities of Iran have produced 10 – 25% more BY compared to the improved variety, Attila. Evolutionary populations of wheat tested in Iran have seen yield gain of 2 – 9% and 20 – 28% compared to the yield of Azar2 and Attila varieties, respectively. Azar2 and Attila are the modern improved varieties.

Jordan: Some barley populations such as BEP5 (*Ghweir EP*) gave the highest GY (945kg/ha), having a yield advantage of 13.3% over high yielding pure stand variety (Local barley). Similarly, BEP1 (Ramtha east EP), BEP5 (Ghweir EP), BEP6 (ACSAD EP) and BEP8 (ICARDA BYT EP) have produced higher BY as pure stands varieties. In summary, BEP5 (*Ghweir EP*) was the winner population for both GY and BY.

Nepal: Beans (at Jumla) and rice populations (at Jumla and Lamjung) were tested in Nepal. The original bean populations (BeEP1 – BeEP4) and populations composed through artificial selections (BeEPM, BeEPF & BeEPB) have yielded higher than the pure stand (BePS2) improved variety, *Trishuli* (Fig. 4).

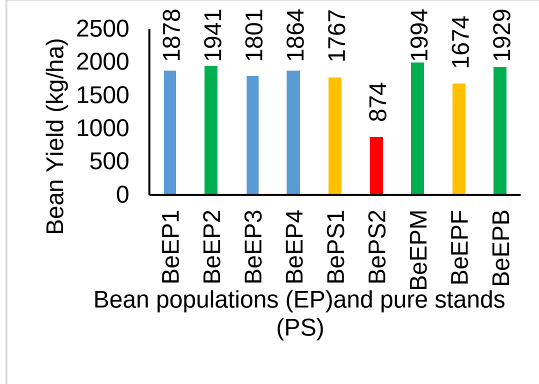

Figure 4. Average GY of beans Jumla, Nepal.

- ✓ Yield gain of 92% (BeEPF) - 128% (BeEPM) was obtained ove BePS2 (pure stand improved variety).
- ✓ Similarly, GY gain of 2% (BeEP3) to 13% (BeEPM) was obtained ove BePS1 (the local landrace).
  - This shows that supporting natural selection through artificial participatory selection could accelerate improvement for GY.

Rice EPs performance in Nepal

At both test locations, the populations of rice have demonstrated superio performance than the pure stand varieties. Yield gain (%) of Ep compared with the two pure stand varieties at Jumla, Nepal shown below

	JU_PS1	JU_PS2
JU_EP1	11.37	8.7
JU_EP2	7.1	4.5
JU_EP3	5.4	2.9
JU_EP4	5.7	3.2

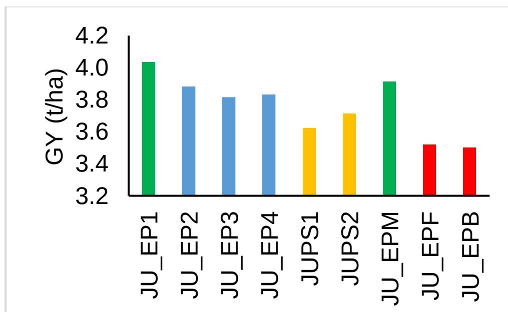

Figure 5. Average GY of rice EPs and PS varieties at Jumla, Nepal.

- ➢ JU_EP1 (mixture of four local landraces) fetched yield gain of 11.37% and 8.7% over the improved variety and local landrace pure stands, respectively.

At Lamjung, EP1 and populations made by selection from 2019 trial by male and female farmers and breeders were superior to both pure stand varieties (Table 2).

Table 2. Average GY, TGW and GY gain (%) of the EPs compared to the two PSs.

Entry	TGW	GY	LAPS1	LAPS2
LA_Ep1	26.68	4.214	4%	16%
LA_EP2	28.67	4.039	-1%	11%
LA_EP3	26.12	3.424	-16%	-6%
LA_EP4	27.63	4.053	0%	12%
LAPS1	26.79	4.065		
LAPS2	24.37	3.630		
LA_EPM_E	27.37	3.208	-21%	-12%
LA_EPF_E	25.93	2.908	-28%	-20%
LA_EPB_E	26.70	3.114	-23%	-14%
LA_EPM_L	28.42	4.478	10%	23%
LA_EPF_L	27.91	4.348	7%	20%
LA_EPB_L	27.74	4.260	5%	17%
Min	24.37	2.91		
Max	28.67	4.48		
LSD (5%)	1.89	0.686		

EP3 (Mixture of improved varieties of similar agroecological domains across Nepal) had average GY lower than both pure stands.

Differential responses of EPs and PSs to biotic and abiotic stresses

The preliminary analysis of data on disease records (scale 1 – 9) showed that some of the tested populations have better tolerate various plant diseases. For instance, less infections of rust, powdery mildew and mosaic virus were recorded on populations compared to the pure stand varieties (Fig.6). On the other hand, the infection scale of Anthracnose's was comparable on some of Eps compared to that of the pure stand varieties. In general, it looks that mixture populations suffered less disease infection than the pure stand varieties.

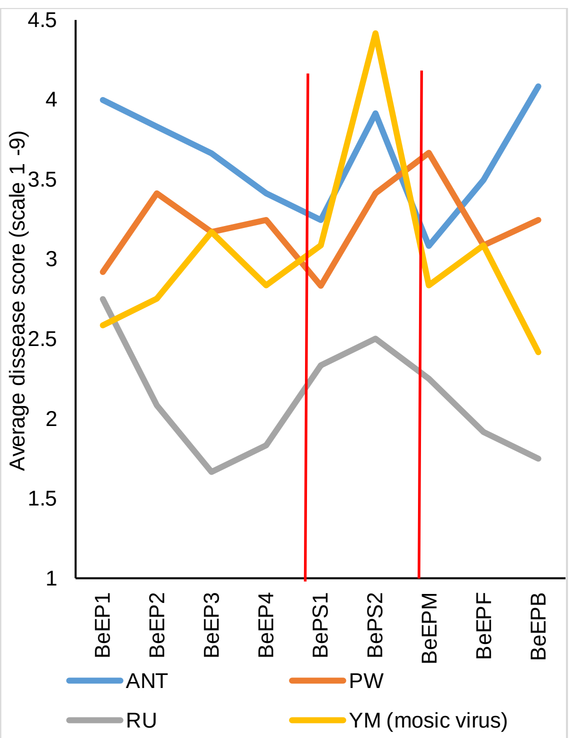

Figure 6. Average disease score of Anthracnose's, rust, powdery mildew and mosaic virus in beans at Jumla, Nepal.

This might be due to the dilution effect of the various component varieties of the populations.

Rice populations tested at Lamjung; Nepal also showed differential response to leaf blast diseases (Fig.7). Rice EP1, EP2, EP4, EPM_L, EPF_L and EPB_L were less infected by blast during 2021 cropping seasons compared to the pure stand varieties.

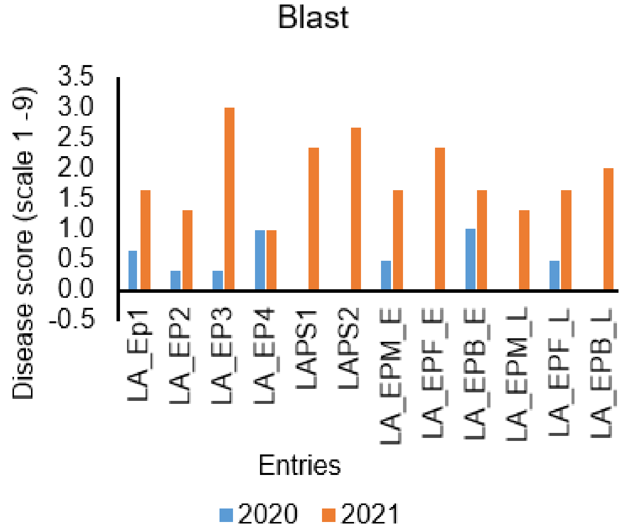

Figure 7. Blast disease score on rice entries at Lamjung, Nepal.

Mixtures also tend to perform well under water and heat stress conditions compared with the improved pure stand varieties. For example, in Iran's Ravansar location, some populations suffer less yield penalty during 2020 drought stressed cropping season than the pure stand varieties (Fig.8).

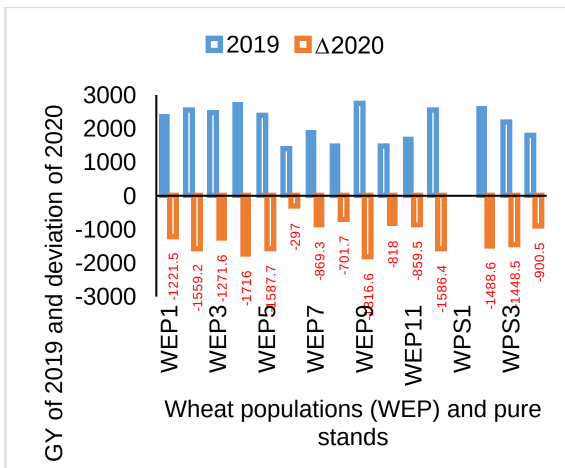

Figure 8. GY deviations of wheat populations and pure stand varieties between 2021 and 2020 cropping seasons at Ravansar, Iran.

WEP6, WEP7, WEP8, WEP10 and WEP11 has suffered lower yield loss during 2020 compared to their performance of the base year than any of the other entries. This imply that these populations have better resisted the impact of confounding drought and heat stress of the area.

Figure 9 showed that Ravansar has experienced two spell water shortage (drought) at early and later developmental stages of the crop.

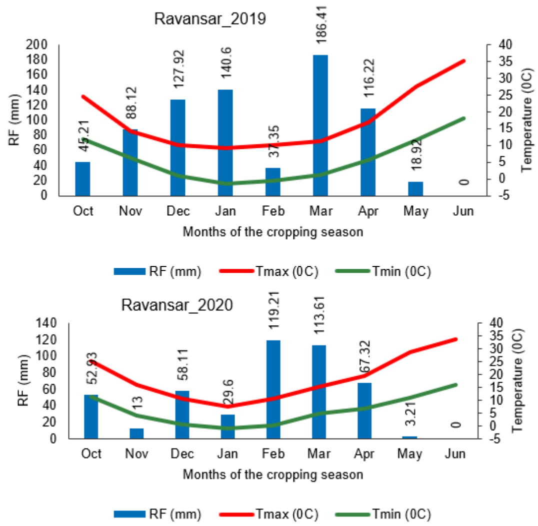

Figure 9. Rainfall, maximum and minimum temperature of 2019 and 2019 cropping seasons of Ravansar, Iran.

During 2020, the crops were exposed to early stage (Nov – Jan) and late stage (April- Jun) drought as the amount of rainfall received may not satisfy the crop water need at these stages. So the above listed populations have better adaptation to such dry spell than the rest of the populations and pure stand varieties.

Study Implications

The results of these studies suggest the potential of farm intra-varietal diversification by planting mixtures or populations to improve farm productivity and resilience of smallholder farmers to the changing environmental conditions. A yield gain of up to 168% has been obtained by growing populations as an alternative to pure stand improved varieties. The results also unlock the potential of local landraces as in most cases the pure stand landraces were better yielder to the improved varieties. The cost benefit analysis conducted (*results not presented*) clearly indicated that growing populations increase farm productivity and profitability, in most cases. Higher yields and reduced external input uses were factors supporting farm profitability.