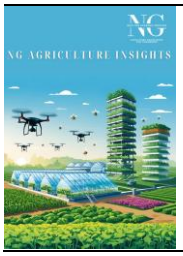

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Heterosis in the Field: Why Hybrids Perform Better than Landraces

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A B S T R A C T

Heterotic responses of hybrid varieties lead to better performance of crops than conventional landrace varieties. Hybrids, which result from the known crossing of genetically distinct parent lines, are found to exhibit hybrid vigour in terms of increased yields, homogeneous growth, and the ability to resist biotic and abiotic stress factors. Landraces are locally adapted varieties that have been farmer chosen and provide the elements of genetic diversity, low-input resilience and cultural importance. Hybrids work best in commercial, high-input forms of farming, but landraces are still significant in marginal areas as well as sources of future breeding material. The maintenance of a balance in the seed choice, i.e. productive seed like hybrids and conservation seed, which are landraces, can increase the sustainability of the farms. Realising the strengths and weaknesses of the two kinds of varieties will enable the farmers to make informed choices that are suitable to their agro-ecological location, availability of resources and production objectives.

Keywords: genetic diversity, heterosis, hybrid varieties, landrace cultivars, sustainability

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1. INTRODUCTION

Agriculture has traditionally formed the basis of life in rural areas; however, as the population grows, as a changing climate and as the requirements of the market increase, the need has become to develop crop performance. The modern day farmer is confronted by two issues of increasing food production on reduced area, as well as ensuring quality and profitability. Tried-and-true crop strains called landraces have been in use by farming-based people over generations to provide stability and adaptability to local surroundings. But their production is sometimes low, and they are not always of the quality or uniformity required by modern markets. Here, crop improvement, especially in terms of the development of hybrid varieties, is critical. Hybrid seeds come about after two genetically different parent plants are selectively cross-fertilised to give offspring that show the best characteristics of both. This effect, also known as heterosis or hybrid vigour, enables farmers to produce more, be more resistant to diseases and adapt more than the old varieties (Muralidharan et al., 2022). Hybrid varieties are able to yield an additional 20-30 per cent over landraces, thus increasing farm incomes substantially in numerous situations (Ansu et al., 2023). They also provide uniform crops more easily when managed well, making harvesting and marketing easy. Emerging smart technologies-IoT sensors, ML-based decision support, and digital advisories-can de-risk hybrid cultivation by improving input timing and management precision, thereby raising farmers' willingness to adopt hybrids over landraces (Prusty et

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al., 2025). As much as the advantages of hybrids cannot be overstated, the need and value of landraces should not be discarded because they will continue to contribute to genetic diversity and cultural heritage. Crop improvement is therefore not only about superseding the old with the new, but making an available option of choice to fit the needs and resources as the agricultural environment continues to change.

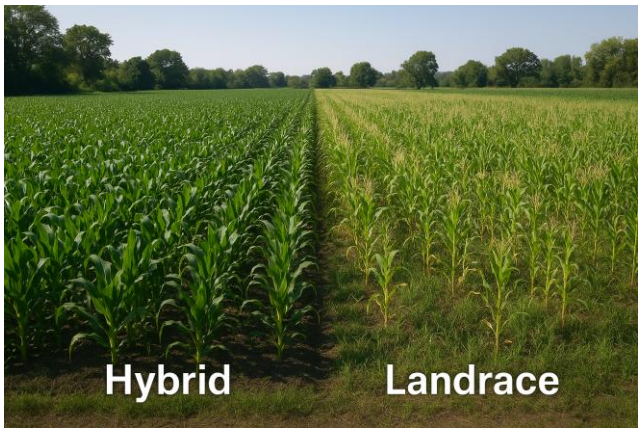

Figure 1. Split-Field Comparison: Hybrid (Left) vs Landrace (Right)

2. WHAT ARE LANDRACES AND HYBRIDS?

In farming, it is important to consider the seeds used by the farmer since this will be a determinant of the harvest. Of the numerous options available, the two types of crop varieties that are commonly raised together as a comparison include landraces and hybrids. Landraces are the folkloric crop varieties developed and maintained by farmers over the generations. They tend to be very much attuned to local environments, climate, soil and agriculture. They are also open-pollinated varieties, which are naturally bred, and their seeds are generally replanted again every season. Landraces may have high values in terms of resilience, taste, cultural importance, and as plants that can be cultivated under low-input conditions, but are not often higher- or more regular yielding than modern varieties.

Hybrid varieties, on the other hand, can be obtained by a scientific process that involves crossing two genetically different parent lines in order to obtain a progeny better than the parents. These children, or F1 hybrids, show what has been termed heterosis or hybrid vigour, an obvious increase in yield, resistance and growth attributes (Temiz & Gökmen, 2023). In contrast to landraces, hybrid seeds must be bought annually since the hybrid seeds harvested at the end of a growing season, with the purpose of saving and replanting them, deliver unpredictable results and poorer performance. Hybrids tend to be more understanding of irrigation and fertilising and can hence be used in commercial or high-input farming.

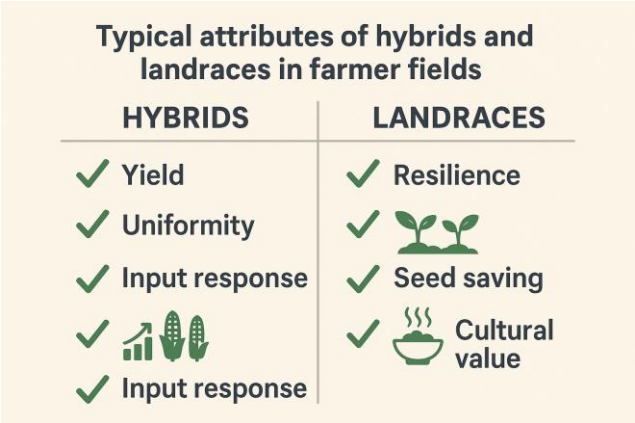

Figure 2. Contrasting Attributes of Hybrids and Landraces in Farmer Fields

3. WHAT IS HETEROSIS (HYBRID VIGOUR)?

Heterosis, also referred to as hybrid vigour, is a biological phenomenon in which the progeny of two genetically different parent plants possesses better traits than those parents have. Simply stated, a hybrid is the combination of two different varieties of the very same growing crop, and, as a result, it is common that the hybrid grows faster, produces more and stands the stresses better than its parents do. This is not a fortuitous advantage; rather, the combination of various genetic characteristics that are complementary to one another is what brings this advantage. The scientific rationale of heterosis is the ability to mask out harmful genes and the ability to express dominant and favorable genes of both side of the family (Wang et al., 2024).

The aspects of heterosis are very simple to notice in practical farming. It is common to find hybrid crops to gain an additional 20 -30% over conventional or landrace varieties. This increased productivity is especially significant to the farmers who must utilize all the land and resources that they may have at hand. On top of yield, hybrids tend to

have even growth, thicker stems, earlier maturity and better tolerance to pests, diseases and unfavourable climate conditions such as drought or excess rainfall. It is however worth mentioning that the effects of heterosis are very significant in the first generation (F1) of the hybrid. Assuming the farmers save and reuse hybrid crop seeds, the hybrid crop (F2) could yield inferior results owing to genetic assortments. It is on this basis that hybrid seeds are usually bought new every season. To conclude, heterosis, in the modern agriculture sector, is a very effective component in ensuring that farmers can get improved yields per unit area of land.

4. ADVANTAGES OF HYBRIDS OVER LANDRACES

There are a number of advantages associated with hybrid varieties, which render them very appealing to farmers, particularly those who aspire to have greater income and effective agricultural outputs. Among the most important ones is increased yield potential. Hybrid crops have the ability to give 2030 percent more than the traditional landraces because of heterosis under similar conditions. This led to productivity boosting which enables farmers to generate higher returns on the same piece of land thereby making farming more economical.

The other significant gain will be in terms of evenness in growth and maturity. The hybrid plants have a tendency to mature at the same rate and attain maturity at the same time, making field management, harvesting and marketing easy. By contrast, however, landraces tend to be uneven growing, and the harvesting is labor-intensive and thereby less efficient. There is also improved quality of produce in hybrids-grain size in cereals or shape, colour and firmness in vegetables. This conformity and quality makes the hybrids more attractive to the traders and consumers. Hybrids also have a high level of tolerance to biotic and abiotic stresses, like resistance to pests and disease, drought tolerance, and the ability to resist different climates (Hussain et al., 2022).

5. BUT WHAT ABOUT LANDRACES? WHY DO THEY STILL MATTER?

As much as hybrid varieties have transformed modern-day farming, landraces, which are our traditional crop varieties, have a great value even today. Farmers have created and cultivated these varieties, and thus they are very much attuned to the local agro-climatic situations. Now these have undergone a natural evolution, with no breeding association, over millennia of breed selection by farmers. Landraces tend to be more adapted to nutrient-limited or marginal conditions and capable of survival in conditions of low fertilisers, irrigation and/or chemical protection. Genetic diversity is one of the greatest attributes of landraces. More than hybrid varieties, landraces have a vast number of genetic qualities. Such variation allows them greater resistance to abrupt outbreaks of pest or disease and long-term sustainability in cropping systems. Such genetic variance is important to breed future crops with better tolerance to either drought, salinity or heat in the face of climate change (Liu et al., 2024).

There is also cultural and culinary significance on landraces (Scarano et al., 2020). Communities also want to access many of the varieties as they have a unique taste, aroma and nutritional quality. As an illustration, the native rice in Odisha is more popular during rituals, festivals, or even traditional recipes. Other than being representatives of food, they are symbols of local identity and heritage. Landraces represent one of the sources of genetic materials to scientists and breeders. They are employed as parental resources in breeding activities to come up with new hybrid. Therefore, landraces need to be maintained- not only because it assures the continued maintenance of cultures and food security but also due to the very future of crop improvement.

6. STRIKING A BALANCE: WHEN TO CHOOSE WHAT?

When to prefer hybrids and when landraces has nothing to do with which one is better in general, but whatever fits well in a given context. Both varieties of seeds have their purposes in contemporary agriculture and the point is that farmers need to reach the golden middle. Blockchain and IoT-enabled extension platforms strengthen traceability and last-mile delivery of certified hybrid seed and inputs, reducing counterfeit risk and improving timely access relative to farmer-saved landrace seed (Suman et al., 2024). The more appropriate place to use the hybrid varieties is a commercial farming system where the objective is the maximisation of yield and profit. When

there is irrigation, fertilisers, and markets readily available, and a farmer is cultivating crops to sell, hybrids can help him/her to revolutionise his/her business. They possess similar growth and high yields and the preferred traits to the market making them suitable for intensive farming.

Low-input, subsistence farming on marginal land often benefits landraces more than any other kind of farming. Landraces have proven to be tastier options that work well in remote or rain-fed areas where there is a limited availability of inputs since they are more locally adapted to the stresses, such as poor soils, uncertain rainfall, and pest pressure. They even make perfect home consumption, especially when the farmers have some interest in flavor, historic recipes, or seed-saving.

7. WHAT FARMERS SHOULD KNOW BEFORE SWITCHING

Though the advantages of hybrid seeds are evident, farmers need to be fully grounded on its use before abandoning the traditional landraces. The initial noteworthy fact is that the hybrid seeds are not reusable. Comparing the landraces with the hybrids, the farmers are able to keep their seeds across seasons but with the hybrid, it is compulsory to buy new seeds each season. It is due to the fact that there can be a loss of vigour and consistency of the hybrids in the second generation (F2) and a lower level of production and odd crop characteristics. Hybrids need improved crop management in order to fully realise their potential. This embraces irrigation at the right time, fertilisation in equilibrium, and pest and disease management. The farmers accustomed to growing landraces by using very little inputs may require training or extension services in order to effectively deal with hybrid crops. The desired yield benefits of hybrids can fail to occur without good management.

The other issue is cost. Hybrid seeds tend to be more costly as compared to the traditional ones, and since one has to buy them every season, they increase the recurring expenses of agriculture. Hence, farmers must determine their capacity to finance and supply inputs needed to facilitate hybrid farming. Insights from women extension personnel in Odisha show that farmers weigh perceived hybrid yield gains against seed replacement costs and cultural preference for landraces, underscoring the need for tailored advisories (Saha et al., 2024). It is also prudent to test the hybrid varieties on a few acres of land before making the switch to see how they perform in regard to the local conditions. Hybrids have the potential to benefit the farming households through proper planning, advice of the agricultural officers as well as through a good source of seeds. However, it is important to make an informed decision so that the benefits are larger than incurred costs.

Figure 3. Management Essentials for Successful Hybrid Cultivation

8. CONCLUSION

Whether to adopt hybrid varieties or landraces is not an issue of determining who is superior to the other but rather, the realization of the distinct purposes and functions of the two kinds of varieties in modern agriculture. The science of heterosis through hybrids has changed the way one farms by giving better yields, quality and resilience when hybrids are well managed. In the case of cultivation driven by the market, where the maximisation of returns is a critical factor, hybrids commonly give the advantage that farmers require so that they can remain competitive and profitable. Landraces, at the same time, cannot be overestimated. They are farmer knowledge, which is modified to local conditions and cultural demands. Not only do their genetic variations make them sustainable to sustain low-input agricultural practices but they also provide a vital foundation upon which the cultivation of crops can be enhanced in the future. New hybrids would not be developed without the landraces. Both of them have to be maintained and encouraged in order to have a healthy and sustainable future of farming. An

integrated approach with farmers, researchers and extension agents is needed to see that informed decisions are made, where hybrids are used because they are better, and land races are preserved because they are sustainable. The development of agriculture has to be inclusive, realistic and has to balance out. Finally, a shrewd farmer is the one who can tell the locations of the hybrid seeds to gain market competence, and the conditions where the landraces would be the best options for security and sustainability. So in the modern world, it is not only better seeds that produce the best harvest-better decisions do the same.

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