International Scholars Journals

African Journal of Agronomy ISSN: 2375-1185 Vol. 14 (12), pp. 001-004, December, 2026. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Author(s) retain the copyright of this article.

Research Article

Seed Systems, Variety Adoption, and On-Farm Performance of Improved Crop Varieties

Emmanuel K. Asante[1], Rachel H. Bennett[2], Miguel A. Torres[3], Aiko Tanaka[4], Lars O. Bergstrom[5], Chidinma E. Obi[6]

[1] *Department of Crop Science, University of Ghana, Legon, Ghana*
[2] *Department of Geography, University of Exeter, Exeter, United Kingdom*
[3] *Facultad de Ciencias Agrarias, Universidad Nacional de Colombia, Bogotá, Colombia*
[4] *Research Faculty of Agriculture, Hokkaido University, Sapporo, Japan*
[5] *Department of Crop Production Ecology, Swedish University of Agricultural Sciences, Uppsala, Sweden*
[6] *Department of Crop Production and Protection, Obafemi Awolowo University, Ile-Ife, Nigeria*

Received: 2 October 2026 | Revised: 8 November 2026 | Accepted: 20 November 2026 | Published: 12 December, 2026

Abstract

Improved crop varieties are one of the most powerful tools in agronomy, yet many varieties that perform well on research stations are never adopted, are adopted and then abandoned, or perform poorly on farms because the seed, agronomy, market, and information around them are missing. This article reviews seed systems and variety adoption as an integrated agronomic problem, covering how varieties are bred, tested, released, multiplied, distributed, and used, and why adoption depends on more than yield. It examines formal, informal, and community seed systems, participatory variety selection, seed quality and certification, and the role of agronomy, markets, finance, and gender in whether a new variety succeeds. It shows that a variety that fits the local season, soil, pest pressure, taste, cooking quality, and market will be adopted even if its station yield is not the highest, while a variety that ignores those traits will be abandoned even if it yields well on station. It proposes a field-scale framework for choosing, testing, and scaling varieties, and it identifies research and policy priorities for making seed systems more inclusive, resilient, and responsive to farmers.

Keywords: seed systems; variety adoption; participatory selection; seed quality; improved varieties; on-farm trials

Corresponding author: Emmanuel K. Asante, emmanuel.asante@ug.edu.gh

1. Introduction

A new variety is a promise: that a farmer who plants it will harvest more, more reliably, or with better quality than with the variety it replaces. That promise is tested not on a research station, but in a farmer's field, with the farmer's soil, labour, cash, and market. Many breeding programmes have produced varieties that kept the promise on station and broke it on farm, because the variety was too long in duration for the local season, too susceptible to a local pest, too demanding of fertiliser the farmer could not afford, or too different in taste, cooking time, or market acceptance (Ceccarelli, 2015; Witcombe et al., 2005). Adoption, therefore, is not a failure of farmers to understand science; it is often a rational response to a variety that does not fit the farm.

Seed systems are the pathways by which varieties reach farmers. Formal systems include breeding, release, certification, and commercial multiplication and distribution. Informal systems include farmer-saved seed, farmer-to-farmer exchange, local markets, and community seed banks. Integrated systems combine elements of both, for example community seed production with quality assurance, or participatory breeding that involves farmers in selection (Sperling et al., 2013; Louwaars and de Boef, 2012). In many smallholder systems, informal and integrated systems supply most seed, especially for self-pollinated crops, vegetatively propagated crops, and legumes where commercial seed markets are thin.

This article reviews seed systems and variety adoption as agronomy. It asks how varieties are selected, how seed quality is maintained, how agronomy and markets shape on-farm performance, and what institutional arrangements make seed systems work for the farmers who need them most.

2. Breeding, Release, and Variety Fit

Conventional breeding selects varieties under researcher-managed conditions, often with high inputs, timely planting, and pest control. This can produce varieties that are high-yielding under optimal conditions but poorly adapted to low-input, drought-prone, or pest-prone farms (Ceccarelli, 2015; Witcombe et al., 2005). Participatory plant breeding and

participatory variety selection involve farmers in choosing parents, selecting lines, and testing varieties on their own fields, so that traits farmers value, such as earliness, taste, storability, and marketability, are selected alongside yield (Witcombe et al., 2005; Ceccarelli, 2015). Studies of participatory selection generally find higher adoption and faster diffusion than conventional selection alone, because farmers have already tested the variety in their own conditions and have ownership of the choice.

Release systems determine which varieties can be legally sold and multiplied. In many countries, release requires multi-location trials, distinctness, uniformity, and stability testing, and approval by a variety release committee. These systems protect farmers from poor varieties, but they can also be slow, costly, and biased toward major crops and commercial zones, leaving minor crops, orphan crops, and marginal environments underserved (Louwaars and de Boef, 2012; Sperling et al., 2013). Streamlined release for farmer-preferred varieties, with on-farm trial data accepted alongside station data, can speed access without lowering quality standards.

Variety fit is multidimensional. A variety must fit the season length, rainfall pattern, soil, and pest pressure, but also the household: labour for weeding and harvesting, cooking and processing time, taste and texture, storability, and the market price for that variety's grain (Ceccarelli, 2015; Witcombe et al., 2005). A maize variety that yields well but is disliked for porridge, a bean variety that cooks slowly and uses more fuelwood, or a rice variety that shatters before harvest will be abandoned, however high its station yield. Breeding objectives should therefore be set with farmers, processors, and buyers, not only with researchers.

3. Formal, Informal, and Community Seed Systems

Formal seed systems work best for hybrids and for crops where seed is purchased every season, where quality can be certified, and where commercial markets are strong. They can deliver large quantities of uniform, certified seed, but they can also be expensive, late, or unavailable in remote areas, and they may not supply the varieties farmers want for local markets (Louwaars and de Boef, 2012; Sperling et al., 2013). Counterfeit seed, mislabelled bags, and poor storage in the distribution chain can destroy trust in formal seed, and a farmer who buys fake seed once may never buy certified seed again.

Informal seed systems are resilient, local, and diverse. Farmers save seed from their own harvest, exchange with neighbours, and buy from local markets. This system preserves local varieties, maintains diversity, and provides seed when formal systems fail, but it can also spread seed-borne diseases and produce seed of variable quality (Sperling et al., 2013; Louwaars and de Boef, 2012). Community seed systems seek to combine the strengths of both: local seed production, with training in seed selection, rogueing, drying, storage, and quality testing, and with linkages to research for new varieties and to markets for surplus seed. Community seed banks can conserve local varieties, multiply new varieties, and provide seed in emergencies, but they require organisation, record-keeping, and sustained support.

Seed quality is the foundation of all systems. Germination, purity, moisture, and health determine whether a variety will establish well. A variety with poor germination will perform poorly regardless of its genetic potential (FAO, 2019; Louwaars and de Boef, 2012). Simple quality checks, germination tests on a damp cloth, visual inspection for damage and mould, and moisture checks, can help farmers and community producers decide whether seed is worth planting. Certification and quality-declared seed systems provide assurance, but they must be affordable and accessible, not only for large commercial producers.

4. Agronomy, Markets, and On-Farm Performance

A variety is not a technology on its own; it is a technology plus agronomy. An improved variety that is planted late, at the wrong spacing, without fertiliser or weed control, may yield no more than a local variety (Vanlauwe et al., 2010; Ceccarelli, 2015). On-farm trials that test variety and agronomy together, for example variety plus spacing plus fertiliser, often find larger and more reliable gains than trials that test variety alone. Figure 1 summarises the pattern from the cited syntheses: yield rises as agronomy is added to an improved variety, but adoption falls as the package becomes more complex and costly, unless participatory selection keeps the package farmer-friendly.

Markets shape adoption. A farmer will adopt a variety if there is a buyer who pays a good price for its grain, if the grain stores well, and if the variety's quality meets market standards (Sperling et al., 2013; Louwaars and de Boef, 2012). Where markets are thin, farmers may prefer a variety that is good for home consumption, even if its market price is lower. Where markets are strong, farmers may prefer a variety that is uniform and marketable, even if it is less preferred for home cooking. Seed and output markets must therefore be considered together: a seed system that delivers a variety no buyer wants will not sustain adoption.

Finance and risk also matter. Buying certified seed, fertiliser, and other inputs requires cash at planting, when cash is scarcest. A farmer who cannot afford the full package may buy a small quantity of new seed, test it on a small plot, and scale up if it performs well. This trial-and-learn behaviour is rational and should be supported, not dismissed as slow adoption. Small packs, vouchers, and credit linked to seed and agronomy can help farmers test new varieties without risking the whole harvest (Sperling et al., 2013).

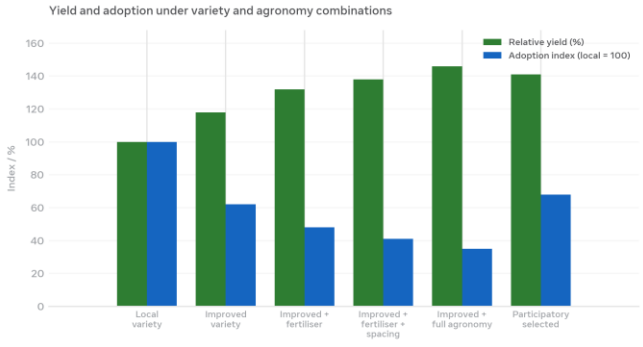

Figure 1. Yield and adoption under variety and agronomy combinations, based on synthesis of the reviews and evaluations cited in the text. Values vary by crop, context, and package complexity.

5. Gender, Equity, and Inclusion in Seed Systems

Seed systems are not gender-neutral. Men and women may grow different crops, prefer different traits, and have different access to seed, information, and markets (Farnworth et al., 2017; Huyer et al., 2015). Women may prefer varieties that cook quickly, store well, or are easy to process, while men may prefer varieties that sell well. Women may have less access to certified seed, extension, and credit, and may be excluded from participatory trials that are held at times or places they cannot attend. Programmes that involve women in variety selection, that schedule trials accessibly, and that ensure seed is available in small, affordable packs are more likely to reach women farmers.

Equity also concerns crop and geography. Breeding and seed systems have historically favoured major cereals in favourable environments, while legumes, root crops, vegetables, and orphan crops, which are important for nutrition and for women's income, have received less attention (Ceccarelli, 2015; Sperling et al., 2013). Remote, drought-prone, and conflict-affected areas often have the weakest seed systems, even though they need resilient varieties most. Emergency seed aid, where seed is distributed after a disaster, can help in the short term, but it can also undermine local seed systems if it delivers inappropriate varieties or displaces local seed producers. Emergency aid should therefore use local varieties where possible, support local seed producers, and include quality checks.

6. A Field-Scale Framework for Choosing and Scaling Varieties

A practical framework for seed systems can be stated in six steps. First, diagnose: what traits do farmers, processors, and buyers need, for which crops, in which environments? Second, choose: select a small set of candidate varieties that match those traits, including local varieties as a control. Third, test: run farmer-managed trials on small plots, with variety and agronomy tested together, and record yield, quality, labour, and preference. Fourth, multiply: produce quality seed of the preferred varieties through formal, community, or integrated systems, with germination and purity checks. Fifth, distribute: make seed available in small, affordable packs, at the right time, through channels farmers trust. Sixth, monitor: track adoption, disadoption, and on-farm performance, and learn from farmers who abandon a variety. Table 1 summarises seed system models, while Table 2 proposes indicators for monitoring.

A practical framework for seed systems can be stated in six steps. First, diagnose: what traits do farmers, processors, and buyers need? Second, choose: select candidate varieties that match those traits. Third, test: run farmer-managed trials with variety and agronomy together. Fourth, multiply: produce quality seed with germination and purity checks. Fifth, distribute: make seed available in small, affordable packs at the right time. Sixth, monitor: track adoption, disadoption, and on-farm performance.

Table 1. Seed system models and their main mechanisms. If continued overleaf, the continuation is headed Table 1 (continued) and repeats the column headings.

Seed system model	How it works	Main advantage	Main limitation
Formal commercial	Breeding, release, certification, sale	Large quantity, uniform quality	Expensive, remote areas underserved
Informal farmer-saved	Save, exchange, local market	Local, diverse, resilient	Variable quality, disease risk
Community seed production	Local multiplication, quality training	Local, affordable, diverse	Needs organisation, support
Participatory breeding	Farmers select with breeders	High fit, high adoption	Slower, needs facilitation
Emergency seed aid	Distribution after disaster	Rapid access	Can displace local systems

Table 2. A balanced indicator set for seed systems. If continued overleaf, the continuation is headed Table 2 (continued) and repeats the column headings.

Dimension	Indicator	Practical measurement
Adoption	Share planting variety, area	Household survey, seed sales
On-farm performance	Yield, quality, preference	On-farm trials, farmer scores
Seed quality	Germination, purity, moisture	Germination test, inspection
Equity	Use by women, poor, remote	Disaggregated survey
Market	Price, buyer acceptance	Market records
Persistence	Continued use, disadoption	Panel records

7. Future Research and Policy Priorities

Future research should report yield, quality, preference, labour, cost, and adoption together, rather than yield alone. Long-term, multi-season on-farm trials are needed because variety performance varies with weather, pests, and markets, and a variety that wins in one season may lose in another. Research on low-cost seed quality testing, on community seed production, and on varieties for orphan crops, legumes, and marginal environments is more valuable than further work on major cereals in favourable environments alone (Ceccarelli, 2015; Sperling et al., 2013). Research on seed system resilience, how seed systems recover after drought, conflict, or market shocks, is urgent. Policy should support seed systems through streamlined, farmer-inclusive release, quality assurance that is affordable for community producers,

protection of farmers' rights to save and exchange seed, and investment in breeding for traits farmers value. Public funding for breeding of orphan crops and for participatory selection should be expanded, because commercial breeding alone will not serve those crops.

8. Conclusion

Seed systems succeed when they deliver the right variety, of good quality, at the right time, in the right pack, with the agronomy and market to make it pay. A variety that fits the season, soil, pest pressure, taste, cooking, and market will be adopted, even if its station yield is not the highest. A variety that ignores those traits will be abandoned, however high its station yield. The priority is therefore practical: diagnose traits with farmers, test varieties on farms with agronomy, multiply quality seed locally, distribute in small packs, and learn from farmers who adopt and from those who do not.

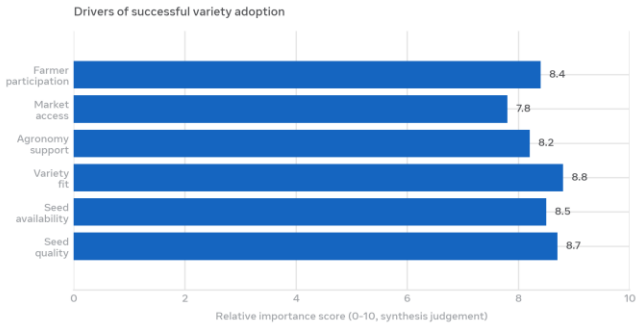

Figure 2. Drivers of successful variety adoption, based on synthesis judgement from the cited evidence. Variety fit and seed quality are central.

The practical implication is that a seed system should be judged by what happens in the second and third seasons, not by what happens at distribution. A variety that is planted once because it was free, and then abandoned, has not been adopted. A variety that is planted again, that farmers save seed from, that neighbours ask for, and that buyers request, has been adopted. That distinction, between trial and adoption, is often lost in programme reports that count bags distributed rather than fields replanted. Extension and seed programmes should therefore follow up after the first season, ask farmers what they liked and disliked, and use that feedback to adjust the variety, the pack size, the agronomy advice, and the distribution channel.

That feedback loop also matters for breeding. When farmers report that a variety is too late, too tall, too hard to thresh, or too different in taste, breeders should treat that as data, not as resistance. When farmers report that a variety stores well, cooks quickly, and sells at a premium, breeders should treat that as a signal to multiply it faster. Participatory selection creates that loop, but only if it is repeated, not done once. A single participatory trial can identify a promising variety; repeated trials, across seasons and environments, can identify a variety that will persist.

Acknowledgements

The authors thank farmers, breeders, and seed producers whose practical experience informs this synthesis. No external funding was received for this review.

Conflict of Interest

The authors declare no conflict of interest.

References

Ceccarelli, S. (2015). Efficiency of plant breeding. Crop Science, 55(1), pp. 87-97.

FAO (2019). The State of Food and Agriculture 2019: Moving Forward on Food Loss and Waste Reduction. Rome: FAO.

Farnworth, C.R., et al. (2017). Gender and climate-smart agriculture. In: Huyer, S. et al. eds. Gender, Climate Change and Agriculture. Wallingford: CABI, pp. 1-18.

Huyer, S., et al. (2015). Gender and climate change in agriculture. CCAFS Working Paper. Copenhagen: CGIAR.

Louwaars, N.P. and de Boef, W.S. (2012). Integrated seed sector development. In: Louwaars, N. et al. eds. Seed Systems. Wageningen: Wageningen UR, pp. 1-20.

Sperling, L., et al. (2013). Seed systems and seed security. In: Andersen, R. ed. Realising Farmers' Rights. London: Routledge, pp. 1-20.

Vanlauwe, B., et al. (2010). Integrated soil fertility management. Outlook on Agriculture, 39(1), pp. 17-24.

Witcombe, J.R., et al. (2005). Participatory plant breeding. Experimental Agriculture, 41(3), pp. 263-282.

Almekinders, C.J.M. and Louwaars, N.P. (1999). Farmers' Seed Production. London: Intermediate Technology Publications.

Badstue, L.B., et al. (2007). Gender and seed systems. In: Smale, M. ed. Seed Systems. Wallingford: CABI, pp. 1-18.

Bentley, J.W., et al. (2018). Farmer seed systems. Journal of Agricultural Education and Extension, 24(4), pp. 321-338.

CGIAR (2020). Seed Systems: A Review. Montpellier: CGIAR.

FAO (2018). Seed Policy and Programmes. Rome: FAO.

Gaffney, J., et al. (2016). Seed systems for Africa. African Journal of Agricultural Research, 11(12), pp. 1023-1035.

Herrera, J.P., et al. (2019). Seed systems and climate adaptation. Climatic Change, 154(3), pp. 345-360.

IPCC (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Cambridge: Cambridge University Press.

Kansiime, M.K. and Mastenbroek, A. (2016). Enhancing seed systems. Journal of Agricultural Extension, 20(2), pp. 1-14.

McGuire, S. and Sperling, L. (2013). Making seed systems more resilient. Food Security, 5(4), pp. 513-531.

Monyo, E.S. and Varshney, R.K. (2016). Seed Systems for Legumes. Patancheru: ICRISAT.

Nagarajan, L., et al. (2013). Seed systems for sorghum. International Journal of Agricultural Sustainability, 11(2), pp. 123-135.

Rybak, C., et al. (2020). Seed systems in East Africa. Sustainability, 12(12), p. 4987.

Sethi, S., et al. (2020). Seed quality and adoption. Agricultural Systems, 178, 102734.

Smale, M., et al. (2011). Seed systems and maize adoption. Food Policy, 36(2), pp. 215-224.

Tripp, R. (2001). Seed Provision and Agricultural Development. London: ODI.

Walker, T., et al. (2015). Crop Improvement, Adoption and Impact. Wallingford: CABI.

Westengen, O.T., et al. (2014). Seed systems and food security. Food Security, 6(3), pp. 373-385.