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Review Article

Weed Management, Herbicide Stewardship, and Non-Chemical Control for Smallholder Cropping Systems

David O. Adebayo[1], Ingrid K. Bauer[2], Tomas R. Alvarez[3], Sara N. Haddad[4], George P. Otieno[5], Laura J. Mitchell[6]

[1] *Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria*
[2] *Institute of Phytomedicine, University of Hohenheim, Stuttgart, Germany*
[3] *Programa de Fitosanidad, Colegio de Postgraduados, Texcoco, Mexico*
[4] *Department of Agriculture, American University of Beirut, Beirut, Lebanon*
[5] *Department of Crops, Horticulture and Soils, Egerton University, Njoro, Kenya*
[6] *School of Agriculture, Policy and Development, University of Reading, Reading, United Kingdom*

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Abstract

Weeds are the most constant and most underestimated constraint in smallholder cropping. They compete for water, nutrients, and light, harbour pests and diseases, slow harvest, and, when left uncontrolled, can reduce yields by a third or more. Hand weeding, the most common control, is slow, back-breaking, and often done by women, at the very time when labour is scarcest. Herbicides can save labour, but when they are used alone, without rotation, without protective equipment, and without attention to resistance, they create new problems: resistant weeds, residues, health risks, and dependence on a product farmers cannot always afford. This article reviews integrated weed management as a practical system, combining timely weeding, crop rotation, cover crops, mulch, competitive varieties, and herbicides used sparingly and safely. It shows that no single method controls weeds well on its own, and that the combination, timed to the critical period of weed competition, consistently outperforms any single method on yield, weed biomass, labour, and profit. It proposes a field-scale framework for planning weed control, and it identifies research and policy priorities for making weed management safer, cheaper, and more effective for smallholders.

Keywords: weed management; herbicide stewardship; integrated weed management; cover crops; herbicide resistance; smallholders

Corresponding author: David O. Adebayo, david.adebayo@ui.edu.ng

1. Introduction

A field that is not weeded is a field that is farmed twice, once for the crop and once for the weeds. Farmers know this, and they spend more time weeding than on almost any other task. In smallholder systems, weeding is often the largest single labour cost, and it falls disproportionately on women and children (Chauhan, 2020; Gianessi, 2013). When weeding is late, the crop loses the competition for water, nutrients, and light during its most sensitive period, and the yield loss cannot be recovered by later weeding, however thorough. When weeding is early and timely, the crop gains a head start that it keeps for the rest of the season.

Herbicides promised to solve this labour problem, and in many systems they have. A single spray can replace days of hand weeding, and can allow a farmer to plant on time, control weeds before they set seed, and reduce the drudgery of weeding. But herbicides are not a complete solution. Used alone, they select for resistant weeds, they require cash, equipment, clean water, and knowledge of dose, timing, and safety, and they can harm the crop, the soil, and the person who sprays them if they are misused (Heap, 2014; Gianessi, 2013). In many smallholder systems, herbicides are bought from informal sellers, mixed without measuring, sprayed without protective equipment, and used year after year on the same mode of action, which is a recipe for resistance and for health risk.

This article reviews integrated weed management as agronomy. It explains how weeds compete, when competition matters most, how cultural, mechanical, and chemical methods interact, and what labour, cash, knowledge, and safety conditions determine whether weed management is adopted or abandoned.

2. How Weeds Compete and When Competition Matters Most

Weeds compete for the same resources as the crop: water, nitrogen, phosphorus, potassium, and light. A weed that emerges before the crop, or at the same time, can grow faster, shade the crop, and take up nutrients before the crop's roots reach them (Chauhan, 2020; Zimdahl, 2013). Weeds also harbour pests and diseases, interfere with harvest, and, if they are allowed to set seed, replenish the weed seed bank for the next season. A single season of poor weed control can therefore create weed problems for several seasons, because the seed bank is the memory of the field.

The critical period of weed competition is the window during which weeds must be controlled to prevent unacceptable yield loss. For most cereals, this window is the first three to six weeks after emergence, when the crop is small and the canopy has not closed (Chauhan, 2020; Zimdahl, 2013). Weeding after this window helps, but it cannot recover the yield already lost. Weeding before the window, or keeping the field clean through the window, is what matters. This is why timing is more important than total weeding effort: two timely weedings can outperform four late weedings.

Figure 1 summarises the pattern from the cited syntheses: yield rises and weed biomass falls as control improves, from no control to hand weeding, mulch, cover crop, herbicide, and the integrated combination, which gives the highest yield and the lowest weed biomass.

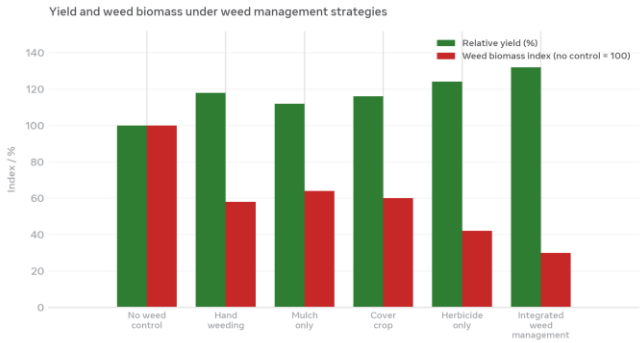

Figure 1. Yield and weed biomass under weed management strategies, based on synthesis of the reviews and meta-analyses cited in the text. Values vary by crop, weed species, and management.

3. Cultural and Mechanical Control: Rotation, Cover, Mulch, and Timely Weeding

Cultural control changes the conditions that favour weeds. Crop rotation breaks weed cycles, because a weed that thrives in one crop may not thrive in the next, especially if the crops differ in sowing date, canopy, and herbicide options (Chauhan, 2020; Zimdahl, 2013). A legume rotation can also add nitrogen and improve soil, so rotation pays in more than weed control. Competitive varieties, with rapid early growth, early canopy closure, and tall stature, can shade weeds and reduce their growth, and should be chosen not only for yield but for competitiveness.

Cover crops and mulch suppress weeds by shading the soil, by competing for water and nutrients, and, in some cases, by allelopathy, the release of chemicals that inhibit weed germination (Chauhan, 2020; Gianessi, 2013). Mucuna, cowpea, lablab, and sunn hemp can provide living cover, fix nitrogen, and produce fodder, but they require seed, labour, and a window in the rotation, and they must not compete with the main crop for water. Mulch, from crop residues or cut vegetation, can suppress weeds and conserve moisture, but it competes with livestock feed and fuel, and it can harbour slugs and diseases in wet areas.

Mechanical control, hand weeding, hoeing, and, where available, inter-row cultivation, is the most common method, and it is also the most labour-intensive. It works best when it is timely, when weeds are small, and when the soil is moist enough to pull weeds easily but not so wet that it compacts. Inter-row cultivation can be faster than hand weeding, but it requires a tool, a row spacing that allows it, and a crop that can tolerate some root disturbance. Mechanical control alone rarely controls weeds in the row, where hand pulling is still needed.

4. Herbicides: How They Help, How They Harm, and How to Use Them Safely

Herbicides can save labour, control weeds before they compete, and allow a farmer to plant on time. Pre-emergence herbicides, applied before weeds emerge, can keep the field clean through the critical period, while post-emergence herbicides, applied after weeds emerge, can rescue a field that was not weeded in time (Heap, 2014; Gianessi, 2013). Herbicides are most effective when they are matched to the weed species, the crop, and the soil, and when they are applied at the right dose, with clean water, at the right growth stage, and with a calibrated sprayer.

Herbicide resistance is the main long-term risk. When the same herbicide, with the same mode of action, is used year after year, resistant weeds are selected, and the herbicide stops working (Heap, 2014; Chauhan, 2020). Resistance can be delayed by rotating herbicide modes of action, by mixing herbicides with different modes of action, by rotating crops, and by combining herbicides with non-chemical methods, so that no single method bears all the selection pressure. A farmer who relies on herbicide alone will, sooner or later, face resistant weeds, and will have no backup.

Safety is equally important. Herbicides can harm the person who mixes and sprays them, the crop if the dose is too high or the timing is wrong, and the environment if they drift or run off. Protective equipment, gloves, long sleeves, a mask, and boots, is essential, but it is often not used because it is hot, expensive, or unavailable. Training on measuring dose, on mixing, on spraying, and on storing herbicides away from food and children is as important as the herbicide itself. Table 1 summarises integrated weed management bundles, while Table 2 proposes indicators for monitoring. The bundles in Table 1 and the indicators in Table 2 should be used together when planning and reviewing a weed management system.

5. Labour, Gender, Cash, and Adoption

Economics determine adoption. Hand weeding is free in cash but expensive in time, and it competes with other tasks, with school, and with off-farm work (Chauhan, 2020; Gianessi, 2013). Herbicides are expensive in cash but cheap in time, and they can allow a farmer to expand area or to plant on time. The choice between them is not only about yield; it is about labour, cash, and risk. A farmer who cannot afford herbicide may weed late, lose yield, and have less cash next season, in a cycle that is hard to break. A farmer who can

afford herbicide but uses it without rotation or safety may gain yield this season and lose it to resistance or health costs later.

Gender shapes who weeds and who decides. Women often do most of the hand weeding, but may have less control over decisions to buy herbicide, less access to sprayers, and less access to training (Farnworth et al., 2017; Huyer et al., 2015). Programmes that involve women in choosing weed control, that provide sprayers women can use, and that schedule training accessibly are more likely to produce durable adoption. Labour-saving weed control, such as cover crops, mulch, and timely herbicide, can reduce women's drudgery, but only if women control the decision to use it and benefit from the time saved.

A practical framework for integrated weed management can be stated in six steps. First, diagnose: which weeds, when do they emerge, and when is the critical period? Second, prevent: rotate crops, use clean seed, and prevent weeds from setting seed. Third, suppress: use cover crops, mulch, and competitive varieties to shade weeds. Fourth, control timely: weed or spray during the critical period, not after it. Fifth, steward herbicides: rotate modes of action, measure dose, use protective equipment, and combine with non-chemical methods. Sixth, monitor: track weed biomass, yield, labour, cost, and resistance over several seasons. Table 1 summarises the bundles that farmers can choose from, while Table 2 proposes the indicators to track. The bundles in Table 1 and the indicators in Table 2 should be read together.

Table 1. Integrated weed management bundles and their main mechanisms. If continued overleaf, the continuation is headed Table 1 (continued) and repeats the column headings.

Bundle	Core practices	Main mechanism	Likely outcome
Hand weeding only	Timely hoeing, pulling	Physical removal	Labour high, weeds in row
Cultural only	Rotation, cover, mulch	Suppression, competition	Lower weeds, slower
Herbicide only	Pre- or post-emergence	Chemical control	Fast, resistance risk
Cultural + mechanical	Rotation, cover, timely weeding	Suppression + removal	Lower weeds, more labour
Integrated weed management	Cultural + mechanical + herbicide	All mechanisms	Highest yield, lowest weeds

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

Dimension	Indicator	Practical measurement
Weed control	Weed biomass, weed cover	Field scores, quadrat
Yield	Yield, stability	Harvest records
Labour and cost	Hours, cost per hectare	Farmer records
Herbicide safety	Protective use, dose, storage	Survey, observation
Resistance	Resistant weeds, escapes	Field scores
Equity	Use by women, poor, remote	Disaggregated survey

6. Future Research and Policy Priorities

Future research should report yield, weed biomass, labour, cost, safety, and resistance together, over several seasons, rather than yield in one season alone. Long-term trials are needed because resistance and weed seed banks change slowly, and a system that looks cheap in year one may look costly in year five. Research on low-cost, safe herbicide application, on cover crops that suppress weeds without competing with the main crop, and on weed identification and timing that farmers can use is more valuable than further trials of herbicide alone (Heap, 2014; Chauhan, 2020). Research on herbicide resistance monitoring, on sprayer design that women can use, and on non-chemical methods that reduce drudgery is urgent. Policy should support integrated weed management through extension on the full system, not only on herbicide, through access to cover crop seed, competitive varieties, and safe sprayers, through regulation of herbicide quality and labelling, and through training on dose, timing, and safety. Subsidies for herbicide should be paired with support for non-chemical methods, so that herbicide is a tool, not a crutch.

7. Conclusion

Integrated weed management is not a choice between hand weeding and herbicide; it is a combination. Cultural methods suppress weeds, mechanical methods remove them, and herbicides, used sparingly and safely, can control them during the critical period. When those elements are combined, timed to the critical period, and stewarded to delay resistance, yields rise, weed biomass falls, and labour and cost become manageable. When one element is relied on alone, or when timing, safety, and resistance are ignored, weed management will fail, however good its short-term result. The priority is practical: diagnose the weeds, prevent seed set, suppress with cover and rotation, control timely, steward herbicides, and monitor over several seasons.

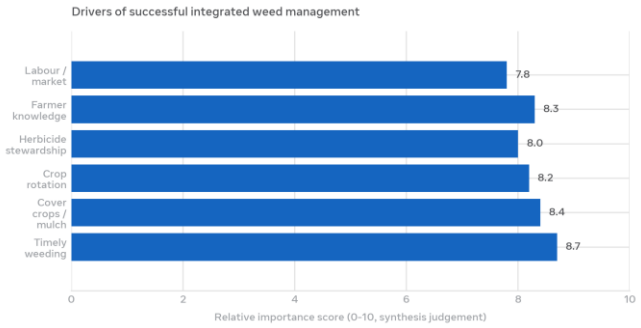

Figure 2. Drivers of successful integrated weed management, based on synthesis judgement from the cited evidence. Timely weeding and cover crops are central.

Figure 2 summarises the drivers that distinguish systems that persist from systems that are abandoned. Timely weeding and cover crops score highest, because they control weeds when it matters and suppress them without chemicals, while herbicide stewardship determines whether chemical control can be sustained without resistance.

The practical implication is that integrated weed management should be introduced as a sequence, not as a package to be adopted all at once. A farmer who first learns to identify the main weeds, then weeds timely on one plot, then tries a cover crop or mulch, can learn what works on that soil, with that labour, and with that cash, without risking the whole farm. A farmer who is told to adopt rotation, cover, mulch, and herbicide at once, with new equipment and new products, may abandon the whole system after one difficult season. Extension should therefore help farmers design a sequence that fits their farm, starting with the practice that gives the clearest short-term benefit, whether that is timely weeding that saves yield, a cover crop that suppresses weeds and feeds livestock, or a herbicide that saves labour at planting.

That sequence also matters for measurement. Farmers who can see change, a field that is cleaner through the critical period, a crop that is taller and greener, a weed seed bank that is falling, are more likely to persist than farmers who are told that weed management will improve in five years. Simple, visible indicators, a weed count in a one-metre quadrat, a comparison of yield on a weeded and an unweeded strip, a record of weeding hours, can make weed management concrete. When farmers measure their own weeds, they become researchers on their own fields, and integrated weed management becomes a system they adapt, rather than a package they receive.

That same logic applies to policy. A policy that subsidises herbicide but ignores cover crop seed, competitive varieties, sprayers, and safety training will produce a herbicide that is used alone, and that selects for resistance. A policy that supports the whole system, cover crop seed, competitive varieties, safe sprayers, protective equipment, and extension on timing and resistance, will produce a system that farmers can sustain. Integrated weed management, in the end, is not about a herbicide or a hoe; it is about a farmer, a field, and a season, repeated until weeds no longer decide the harvest.

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Conflict of Interest

The authors declare no conflict of interest.

References

Chauhan, B.S. (2020). Grand challenges in weed management. Frontiers in Agronomy, 1, p. 3.

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.

Gianessi, L.P. (2013). The increasing importance of herbicides in worldwide crop production. Pest Management Science, 69(10), pp. 1099-1105.

Heap, I. (2014). Global perspective of herbicide-resistant weeds. Pest Management Science, 70(9), pp. 1306-1315.

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

Zimdahl, R.L. (2013). Fundamentals of Weed Science. 4th ed. Amsterdam: Academic Press.

FAO (2019). Conservation Agriculture: A Training Manual. Rome: FAO.

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

Beckie, H.J. and Harker, K.N. (2017). Herbicide resistance and integrated weed management. Weed Science, 65(5), pp. 1-12.

Buhler, D.D. (2002). Challenges and opportunities for integrated weed management. Weed Science, 50(3), pp. 273-280.

Chauhan, B.S., Singh, R.G. and Mahajan, G. (2012). Ecology and management of weeds. Field Crops Research, 132, pp. 1-12.

Heap, I. and Duke, S.O. (2018). Overview of glyphosate-resistant weeds. Pest Management Science, 74(5), pp. 1040-1049.

Hossain, M.M., et al. (2021). Integrated weed management in rice. Crop Protection, 145, 105634.

Jabran, K., et al. (2015). Weed management in wheat. Crop Protection, 74, pp. 1-10.

Knezevic, S.Z., et al. (2002). Critical period for weed control. Weed Science, 50(4), pp. 523-530.

Kumar, V., et al. (2017). Integrated weed management in maize. Field Crops Research, 210, pp. 1-12.

Mahajan, G., et al. (2013). Weed management in direct-seeded rice. Field Crops Research, 149, pp. 1-12.

Mashingaidze, A.B., et al. (2012). Weed management in smallholder maize. Crop Protection, 35, pp. 1-10.

Menalled, F.D., et al. (2001). Ecological weed management. Weed Science, 49(6), pp. 1-12.

Neve, P., et al. (2009). Herbicide resistance and weed management. Weed Research, 49(6), pp. 1-12.

Norsworthy, J.K., et al. (2012). Reducing the risks of herbicide resistance. Weed Science, 60(4), pp. 1-12.

Oerke, E.C. (2006). Crop losses to pests. Journal of Agricultural Science, 144(1), pp. 31-43.

Rana, S.S. and Rana, M.C. (2016). Principles and Practices of Weed Management. Palampur: CSKHPKV.

Swanton, C.J., et al. (2008). Critical period for weed control. Weed Science, 56(1), pp. 1-12.

Vitta, J., et al. (2004). Weed competition and crop yield. Weed Research, 44(2), pp. 1-12.

Westwood, J.H., et al. (2018). Weed management in 2050. Weed Science, 66(3), pp. 1-12.