After the damage: Crop pest and disease losses and next-season production choices in Malawi

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Abstract

Farmers must account for a wide variety of risks in their production decisions, and base those decisions on their experiences and expectations of these risks. Pests and diseases are an important cause of crop production risk globally, but evidence on how smallholder farmers adjust production after pest or disease damage remains limited. This paper studies next season production responses to reported pest/disease-related preharvest crop losses in Malawi, using data from the Integrated Household Panel Survey in a household fixed effects framework to compare households across agricultural seasons. Households reporting such losses use about 25% more non-harvest labor per acre and increase seed acquisition expenditures by about 65% in the following season. I find no significant effects on pesticide or herbicide use, fertilizer use, crop count, planted area, or crop concentration. The results are robust to alternative controls for time-varying factors, including other reported crop losses, and do not appear to be driven by reduced prior crop production value. Responses are strongest after the household's most recent reported pest/disease loss. The evidence suggests that such losses shape targeted adjustments on flexible production margins, especially household labor and seed acquisition, rather than broad reoptimization across agricultural decisions. The results highlight how such losses can affect households beyond the season when they are experienced by driving costly but potentially beneficial input adjustments.

JEL codes: J22, O13, Q10, Q54

Keywords: agricultural shocks; crop pests and diseases; smallholder agriculture; input decisions; Malawi

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Après les pertes : ravageurs, maladies des cultures et choix de production la saison suivante au Malawi

Abstract

Les ravageurs et les maladies sont une source importante de risque pour la production agricole, mais les données sur la manière dont les petits exploitants ajustent leur production après des dommages dus aux ravageurs ou aux maladies restent limitées. Cet article étudie les réponses de production la saison suivante à des pertes pré-récolte déclarées comme liées aux ravageurs ou aux maladies au Malawi. J'utilise les données de l'Integrated Household Panel Survey et un modèle à effets fixes ménage pour comparer les mêmes ménages entre saisons agricoles. Les ménages déclarant de telles pertes utilisent environ 25% de travail non lié à la récolte en plus par acre et augmentent leurs dépenses d'acquisition de semences d'environ 65% la saison suivante. Je ne trouve pas d'effet significatif sur l'utilisation de pesticides ou d'herbicides, l'utilisation d'engrais, le nombre de cultures, la superficie cultivée ou la concentration des cultures. Les résultats suggèrent que ces pertes entraînent des ajustements ciblés sur des marges flexibles, en particulier le travail familial et l'acquisition de semences, plutôt qu'une réorganisation générale des décisions agricoles.

Mots-clés : chocs agricoles ; ravageurs et maladies des cultures ; agriculture familiale ; décisions d'intrants ; Malawi

Déclaration de pertinence et d'originalité

Cet article contribue à l'étude des risques agricoles dans les pays à faible revenu en analysant une source de pertes relativement peu étudiée par les économistes : les ravageurs et les maladies des cultures. Son originalité est d'utiliser des données de panel auprès de ménages agricoles pour étudier les ajustements de production réalisés la saison suivant des pertes pré-récolte déclarées comme liées aux ravageurs ou aux maladies. Les résultats montrent que ces pertes sont suivies d'une hausse du travail agricole et des dépenses d'acquisition de semences, ce qui met en évidence un canal par lequel les risques biotiques peuvent affecter les petits exploitants au-delà de la saison où les dommages sont subis.

1 Introduction

Farmers make crop production decisions based on their expectations of a wide variety of risks. Abiotic shocks—such as drought, irregular rainfall, and flooding—and biotic shocks— including weeds, animal pests, plant pathogens, and viruses—reduce output in the season when damages occur but may also push farmers to adjust future production decisions. A large literature in economics studies household responses to weather shocks, price risk, and agricultural shocks more broadly, but much less is known about how smallholder households adjust production decisions after losses attributed to pests or diseases. Global estimates suggest that such biotic factors account for large potential and realized losses for major crops (Oerke, 2006), and climate change may alter the range and severity of some pest and disease pressures (Dhanush et al., 2015; Garrett et al., 2013; Lamichhane et al., 2015). Pest/disease losses may also differ from many weather shocks because they can be crop- or plot-specific, may reveal information about seed suitability or household management practices, and may be mitigated through targeted changes in labor use, seed acquisition, or crop protection. This paper studies whether smallholder households change input choices and other production decisions after experiencing preharvest crop losses attributed to pests or diseases in the previous agricultural season and considers the potential channels for such effects.

I examine this question in the context of Malawi, where pests and diseases are a prominent production risk alongside weather-related risks (Giertz et al., 2015). Estimating the effects of crop pests and diseases requires information on where they are present and where they cause preharvest losses. High-resolution data on the presence of or risk from different crop pests and diseases over time are rarely available in most low-income settings. Agricultural household surveys often collect information on crop losses from different causes, but they do not typically measure objective pest or disease prevalence at the spatial and seasonal scale needed to link those stressors directly to production decisions. In this study, I use data from the Malawi Integrated Household Panel Survey (IHPS), which includes household reports of preharvest losses to area planted and the causes households attribute to those losses. A reported pest/disease-related crop loss combines pest or disease presence, crop susceptibility, mitigation capacity, realized damage, salience, recall, and attribution. Survey-based crop loss measures therefore require careful interpretation (Markhof et al., 2022). At the same time, reported losses are behaviorally meaningful: farmers make next-season decisions after observing, remembering, and attributing damage to a cause.

The IHPS is well suited for studying farmer responses to crop pest and disease losses because respondents in each survey round report on production decisions, shocks, and outcomes for both the most recently completed (current) agricultural season and the season prior. I use the 2010 and 2013 rounds of the panel to compare households to themselves across waves, using within-household variation in reported pest/disease losses over time. The main specification relates current season crop production decisions to prior season reported pest/disease-related preharvest losses, with household fixed effects, wave fixed effects, household and geographic controls, prior season planting controls, and controls for other reported prior season shocks. This design absorbs time-invariant household differences and common wave shocks and conditions on observed time-varying factors that may affect both crop loss reports and input choices. Although the within-household comparisons should absorb a large share of factors affecting which households report pest/disease losses, some endogeneity may remain. The estimates are therefore best interpreted as within-household associations consistent with responses to reported pest/disease crop losses, rather than as clearly causal estimates of impacts of objective pest or disease exposure.

The central result is that households adjust on flexible input margins. Households reporting a prior season pest/disease-related preharvest loss use about 21 additional days of non-harvest labor per acre in the following season, an increase of more than 25% relative to the mean, and spend substantially more per acre on seed acquisition—a 65% increase. Higher seed acquisition expenditures are accompanied by a greater probability of sourcing seeds from beyond the community and nearest town. I do not find comparable increases in pesticide or herbicide use, fertilizer use, crop count, area planted, or crop concentration. The response is therefore concentrated on margins that smallholder households can plausibly adjust, rather than on formal crop-protection chemicals or broad changes in land allocation and crop mix. Analyses of responses to other reported crop loss shocks show that this pattern is not simply the generic response to any reported preharvest loss.

The results indicate that crop losses can shape production beyond the season in which losses occur. I find limited evidence that the main responses are explained by a simple tightening of the crop production budget following prior season losses. Total input and labor expenditures do not fall, and the labor and seed responses are not explained by observed prior crop production value. The labor response is consistent with increased broad crop management effort in a context where many pest and disease management practices require repeated manual monitoring and control. The seed response is consistent with changed seed acquisition after a salient loss, although the data do not identify seed traits or purchase motives.

Timing patterns show that responses are strongest after the most recent own reported pest/disease loss, consistent with recency, salience, or changes in perceived risk. The results may also reflect persistence in exposure to biotic stressors, since prior pest/disease losses predict current losses. I cannot estimate whether farmer responses to prior pest/disease losses mitigate future damages, but the increases in labor and seed expenditures are consistent with efforts to adjust production in response to perceived or persistent risk. Heterogeneity by extension contact and road access further suggests that these adjustments depend partly on access to information, services, or markets.

These results contribute to work on farm household responses to agricultural shocks and risk in low-income countries. A large literature studies how households cope with shocks through consumption smoothing, livelihood diversification, input choices, and investment decisions (Dercon & Christiaensen, 2011; Dercon & Krishnan, 2000; Dercon et al., 2005; Emerick et al., 2016; Karlan et al., 2014; Porter, 2012). The closest evidence on dynamic production responses comes from work showing that past weather or climate shocks can affect later agricultural investment, input demand, output choices, and seed acquisition decisions (Newman & Tarp, 2020; Nordhagen & Pascual, 2013; Wimmer et al., 2024). Related work from developing contexts shows that recent experience can shape agricultural expectations and decisions (Freudenreich & Kebede, 2022; Guido et al., 2020). I add evidence on a different type of risk, studying next season input adjustment after reported pest/disease crop losses in a low-income smallholder setting and considering the potential role of changes in agricultural expectations.

The paper also contributes to a smaller economics literature on pest and disease risk. Recent work on fall armyworm and other pest-management problems in Sub-Saharan Africa documents farmer perceptions and contemporaneous management responses, including chemical, cultural, and labor-intensive controls (Kansiime et al., 2019; Kumela et al., 2019; Tambo et al., 2020). In higher-income settings, detailed administrative and commercial data make it possible to study crop-protection input responses more directly, such as pesticide purchases following weather shocks (Bareille et al., 2024). My contribution is to study a dynamic response to reported pest/disease damage in smallholder agriculture, where objective pest and disease prevalence data and detailed input-use data are more limited. The results show that reported crop damage is followed by costly increases in household crop labor and seed acquisition the following season, highlighting a practical channel through which pest and disease risk can affect smallholder production beyond the output lost when damage occurs.

2 Conceptual Framework

Farm households make production decisions before many production risks are realized. Input choices, labor allocation, crop choice, and seed acquisition depend not only on current prices and expected returns to different production methods, but also on farmers' expectations about weather, pest and disease pressure, prices, liquidity, and access to information or services. Uncertainty around these factors creates risk, which may be especially important in low-income settings where production risk can directly affect household consumption. Incomplete credit and insurance markets, heavy reliance on household labor and saved or informally sourced seed, and limited access to timely information about future production risks all limit small farm households' ability to manage risk.

A large literature in agricultural and development economics studies production decisions under risk. Weather and price risk affect the composition and profitability of agricultural investment portfolios, and the ability to bear risk varies with wealth and market access (LaFrance et al., 2011; Rosenzweig & Binswanger, 1993). In low-income settings, incomplete credit and insurance markets can make risk central to input and technology adoption. Downside consumption risk can discourage fertilizer use, while insurance, credit, or technologies that reduce downside risk can increase investment in more productive but riskier choices (Dercon & Christiaensen, 2011; Emerick et al., 2016; Karlan et al., 2014).

A smaller but directly relevant literature studies how farmers use realized experience to inform expectations about uncertain factors in production, for example basing expectations about seasonal rainfall on recent weather experience (Guido et al., 2020). Recent shock experience can also affect expectations about future shocks, with the strength of updating varying by household wealth (Freudenreich & Kebede, 2022). A few studies also show that past agricultural shocks can affect later production decisions. Evidence from Vietnam suggests that shock exposure can reduce longer-run agricultural investment (Newman & Tarp, 2020). A structural model of European agriculture suggests that weather shocks can affect farm input demand and output choices beyond the year in which the shock occurs (Wimmer et al., 2024).

Building on this literature, this section presents a simple framework for why reported pest/disease-related crop losses may be followed by changes in next-season production decisions, and for interpreting which channels could explain such responses.

In a benchmark with separable production and consumption decisions, complete markets, and stable beliefs about production risk, prior realized crop losses need not change next-season input choices. A household choosing inputs before the growing season would base its decision on current and expected input and output prices, sources of production risk, and liquidity and labor constraints. In that benchmark, a loss experienced in the previous season affects current production decisions only if it changes one of these decision drivers, or if it is correlated with another time-varying factor that changes them. For example, a reported loss may be correlated with a change in local pest pressure or extension exposure that directly affects current input choices. In general, past crop production losses due to biotic or abiotic shocks may affect current decisions by changing available resources, perceived or known risk, or the expected returns to different management strategies.

Thinking first about the resource channel, a pest/disease-related crop loss decreases harvested output and may therefore reduce cash income, seed retained from production, and the household's ability to finance next-season inputs. If this channel dominates through cash constraints, purchased input use or total input expenditures may fall after losses, especially for households with lower prior production value, fewer assets, or weaker access to credit. A report on smallholders in Malawi estimates that these households spend on average 45% of the value of their crop production on inputs, and that only 6% have access to credit, suggesting crop losses may meaningfully constrain next season liquidity (FAO, 2018). On the other hand, if crop losses reduce the quantity or quality of grain available for seed retention, households may need to replace seed stocks before planting again.

Past losses may also affect decisions through expectations about future risk. For some pests and diseases, a recent loss may reveal persistent local exposure, endemic pressure, crop susceptibility, or gaps in household mitigation capacity. In that case, the household may rationally expect higher future risk after observing a loss. At the same time, recent losses may make pest and disease risk more salient even when objective risk has not changed, for example if the cause of the losses is eliminated. These interpretations are not mutually exclusive: reported losses may provide information about true risk while also increasing the weight households place on that risk when making decisions. Both interpretations imply stronger responses to recent own losses than to older experiences, and potentially different responses to own losses than to reports by other households nearby.

Smallholder farmers could modify input decisions on several margins to protect themselves from a perceived increase in pest or disease risk. First, farmers may increase their use of pesticide or herbicide to directly target the threats they face. This response is more likely when pesticide/herbicide use is more common or for households with greater resources and market access. Second, households may search for different seed sources, purchase seed rather than rely on saved seed, or seek varieties they perceive as better suited to the risks they face. Third, they may rely more heavily on labor-intensive crop management, particularly when purchased protection options are costly, unavailable, or unfamiliar. Farmers may respond by changing land preparation, planting, field monitoring, weeding, crop sanitation, or other management activities. For smallholder farm households, these responses are likely to rely more on household labor.

The strength of these responses should depend on adjustment capacity. Resource channels should be weaker when households have assets, credit, savings, or other buffers, and stronger when a realized loss tightens the production budget. Purchased input increases should be easier when households are closer to roads or markets. Labor-management responses may depend on household labor availability, the ability to hire workers, and access to information about management practices. Extension contact may matter across several channels by changing information, input access, or the perceived returns to particular responses.

The empirical analysis uses this framework to guide interpretation of the results. I first ask whether reported pest/disease-related losses are followed by changes in next-season production decisions, and which margins move. I then use patterns across input expenditures, seed acquisition, labor inputs, timing of reported losses, and heterogeneity by household characteristics to interpret which channels are most consistent with the evidence.

3 Data

I use the 2010-11 and 2013 waves of the Malawi Integrated Household Panel Survey (IHPS), collected by the Malawi National Statistics Office (NSO) as part of the World Bank's Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA). Each wave includes agricultural modules for the current rainy season and the preceding rainy season.[1] For the prior rainy season, households report planting decisions and harvest outcomes by crop, but not detailed input use. Current-season modules include more detailed information on inputs, labor, and farm outcomes. I therefore relate prior season crop loss reports to current season input and cropping decisions, but cannot control for most prior season inputs.

In the first survey wave, the prior and current rainy seasons are 2008-09 and 2009-10, respectively. In the second wave, they are 2011-12 and 2012-13. The survey does not observe the 2010-11 rainy season. The analysis sample is the balanced panel of households that cultivate crops and are

[1] The rainy agricultural season in Malawi generally runs from November to May, though the timing of rainfall and production varies somewhat across space and crops. Some households also cultivate during a second "dry season," but this analysis focuses on rainy-season production, when nearly all farm households grow crops (NSO, 2014).

observed in both waves. This excludes non-farm households, wave 1 households not resurveyed in wave 2, and split-off households surveyed separately in wave 2.

The survey includes a wide variety of information on agricultural production. Households in the sample are typically male-headed with around 5.5 household members and just over 2 plots, on which they plant over 2.5 acres of crops, usually planting 2 crops (Table A1)[2]. Most households grow at least some maize, with no other crop grown by more than half of households. Few households use any pesticide/herbicide, and most households do not report any purchases of seed or fertilizer/chemical inputs[3]. Paying for casual labor accounts for most of the median household's total input and labor expenditures. I do not impute costs for inputs the household does not purchase, such as saved seed, household labor, or land. I calculate the value of crop production by valuing all crops sold by the household at the value for which they were sold, and then back out prices to value unsold crops as follows. If the household sold the crop, all unsold quantity of that crop is valued at the household sales price. For crops the household did not sell, I use the median price at the lowest level of geography (EA, district, region, or country) for which I observe at least 5 households selling the crop. Crops with fewer than 5 sales observations nationally are not valued. I winsorize top 1% of continuous variables, and values in Malawian Kwacha (MK) are all expressed in 2013 values to account for inflation[4].

The treatment variable is based on self-reported preharvest crop-area losses. For each crop on each plot, respondents report whether the area harvested was smaller than the area planted and, if so, list the top two reasons for the area loss. I define a household as reporting a prior-season pest/disease-related preharvest loss if it reports losing planted area on any plot because of damage from pests or diseases.[5]

This measure captures reported realized crop losses rather than objective pest or disease exposure.[6] It does not identify the biological pest or disease, local prevalence, losses that reduce yields without reducing harvested area, or the severity of losses within harvested area. It may also miss cases where pest or disease pressure was present but successfully mitigated, or where pests and diseases contributed to losses but were not among the top two reported reasons. Households that report pest/disease-related losses may differ from other households because their crops were more vulnerable, mitigation options were weaker, or realized damage was more salient. The empirical

[2]Households are asked about 27 crop categories, and I count the number of crops using these categories, though I aggregate categories when reporting area planted.

[3]Most small farmers in Malawi rely on saved seed and informal local seed exchange networks (Nordhagen and Pascual, 2013).

[4]For reference, in 2013 1 USD was worth around 330 MK at international exchange rates.

[5]The survey combines insects and diseases in a single reason code, so I use a combined pest/disease measure throughout. As far as I am aware there were no major insect or crop disease outbreaks in the years included in the study, so the shocks do not represent some broad aggregate spread of a new pest, as is the case for example with the later arrival of the Fall Army Worm. Instead they will reflect either the circulation or proliferation of stressors already present in Malawi or a change in production decisions that made households more vulnerable.

[6]Objective data on crop pest and disease prevalence at a fine geographic and temporal level are not available in Malawi or most of sub-Saharan Africa. Although recent efforts are being made to track the spread of certain pests in low-income countries, such as Fall Army Worm across Sub-Saharan Africa, these data are too recent to match to existing panel survey data from households in the affected areas.

strategy uses the panel structure of the data to absorb time-invariant household differences and controls for prior planting decisions and other reported shocks, but the object of interest remains household responses to reported realized crop losses.

Table 1 summarizes reported prior and current rainy season crop losses in the panel sample. Reported preharvest losses are common. In wave 1, 48.0% of households report some prior season preharvest loss and 61.8% report some current season preharvest loss. Drought and rain/flood-related losses are most common. Pest/disease-related losses are less frequent at the household level, reported by 3.8% of households in wave 1 for the prior season and 8.1% for the current season. The wave 2 difference is small for prior season pest/disease reports, but current season reports increase by 4.2 percentage points.

Table 1: Household reports of preharvest and postharvest losses, by season and wave

	Wave 1 (SD)	Wave 2 difference (SE)
Prior season		
Any preharvest crop loss	0.480	0.124***
	(0.500)	(0.042)
Pest/disease preharvest crop loss	0.038	-0.001
	(0.192)	(0.010)
Drought preharvest crop loss	0.158	0.076***
	(0.365)	(0.024)
Irregular rain/flooding preharvest crop loss	0.158	0.044**
	(0.365)	(0.022)
Labor-shortage preharvest crop loss	0.051	0.016
	(0.221)	(0.012)
Other preharvest crop loss	0.207	0.050
	(0.405)	(0.034)
Any sampled EA household reports	0.309	-0.012
pest/disease loss	(0.462)	(0.069)
Any postharvest crop loss	0.128	-0.060**
	(0.335)	(0.028)
Current season		
Any preharvest crop loss	0.618	0.040
	(0.486)	(0.063)
Pest/disease preharvest crop loss	0.081	0.042***
	(0.273)	(0.016)
Drought preharvest crop loss	0.115	-0.165***
	(0.320)	(0.045)
Irregular rain/flooding preharvest crop loss	0.318	0.083
	(0.466)	(0.055)
Labor-shortage preharvest crop loss	0.054	0.025
	(0.226)	(0.020)
Other preharvest crop loss	0.294	0.132**
	(0.456)	(0.055)
Any sampled EA household reports	0.490	0.176**
pest/disease loss	(0.500)	(0.089)
Any postharvest crop loss	0.099	0.013
	(0.298)	(0.020)

Note: This table shows the wave 1 mean and the wave 2 difference for indicators of reported shocks in different seasons, estimated from separate regressions. Preharvest loss variables are indicators for whether a household reported losing planted area for any crop on any plot due to a given cause. "Any EA pest/disease loss" indicates whether any sampled household in the enumeration area reported a pest/disease-related preharvest loss. Postharvest loss variables indicate any reported postharvest crop loss in the relevant season. *p<.10, **p<.05, ***p<.01.

Reported pest/disease-related losses are not concentrated in a single part of Malawi. In a typical season, between one third and one half of households are in an enumeration area where at least one sampled household reports a pest/disease-related preharvest loss, and around three quarters of districts have at least one sampled household reporting such a loss. These local reports provide useful context for the measure, but should not be interpreted as objective pest or disease prevalence. Table A2 provides summary statistics on pest/disease loss reports over time at the household and enumeration area levels. Because pest or disease prevalence is likely highly correlated over space, the main specifications cluster standard errors at the district level, and I report enumeration-area clustering as a robustness check.

Weather is an important source of time-varying confounding because it can affect both crop loss reports and current agricultural outcomes. I therefore test the robustness of the results to controlling for local weather in the prior and current season, and also control for other reported preharvest shocks.

Table A1 compares household characteristics and prior season production variables by whether the household reports a prior season pest/disease-related preharvest loss in a given wave. Households reporting such losses look similar to other households on many characteristics, including age and gender of the household head, household size, distance to roads, rainfall, elevation, and soil characteristics. The main differences are on agricultural margins: households reporting pest/disease-related losses cultivate more plots and crops (but not more area) and are more likely to report other preharvest and postharvest losses. These differences motivate the household fixed-effects design and the inclusion of controls for prior season planting decisions and reported shocks.

4 Empirical Strategy

My empirical approach uses household fixed effects to compare production decisions by the same households across waves, depending on whether they reported a pest/disease preharvest loss in the prior rainy season. This approach absorbs time-invariant household differences that may affect both vulnerability to crop losses and production choices. With wave fixed effects and controls for time-varying household characteristics, prior planting decisions, and other reported prior season shocks, the estimates describe within-household changes associated with reported pest/disease crop losses. Household fixed effects regressions take the form

$$Y_{idt} = \alpha + \beta PDShock_{idt} + H'_{idt}\theta + F'_{idt}\gamma + \tau_t + \mu_i + \epsilon_{idt}, \tag{1}$$

where Y_{idt} is a current season household production or livelihood outcome for household i in district d in survey wave t.[7] $PDShock_{idt}$ is an indicator for whether the household reported a pest/disease preharvest crop-area loss in the rainy season before wave t. The household fixed effect μ_i absorbs

[7]Most variables in this specification are reported at the household level, so I conduct the analysis at that level. Preharvest loss data and some production decisions are collected at the crop or plot level, but the main analysis aggregates these measures to the household-wave level.

time-invariant household characteristics, and the wave fixed effect τ_t absorbs common differences across survey waves. I cluster standard errors at the district level; Table A8 reports a robustness check clustering at the enumeration-area level.

The vector H_{idt} includes household characteristics and geographic variables that may affect both vulnerability to reported losses and current production choices.[8] Many of these variables vary little over time and are largely absorbed by household fixed effects, but I retain them to account for any measured changes across waves. The vector F_{idt} includes farm production variables and other reported shocks for the prior season. These include crop count, area planted to specific crop categories, other prior season preharvest loss categories, and postharvest crop losses.[9] The data do not include information on prior season crop inputs. These controls account for differences in prior planting decisions and for the fact that pest/disease losses may co-occur with other reported crop losses.

The coefficient β is the within-household association between reporting a prior season pest/disease preharvest loss and the current season outcome, conditional on the fixed effects and controls. I interpret β as evidence on whether households change production decisions after reported pest/disease losses, rather than as the causal effect of objective pest or disease exposure.[10] Household fixed effects address fixed differences across households, but they do not remove unobserved time-varying factors such as changing pest pressure, weather-mediated pest risk, local input market conditions, extension exposure, or changes in reporting behavior.

The identifying comparison is therefore within-household and conditional. The estimates compare the same household across two observed waves, after accounting for common wave effects, observed changes in household and geographic characteristics, prior planting decisions, and other reported crop losses. This is a stronger comparison than cross-sectional selection on observables, which is often necessary in studies using self-reported shocks without household panel data (Dercon et al., 2005; Lazzaroni & Wagner, 2016; Nguyen et al., 2020; Porter, 2012; Teklewold et al., 2013; Tibesigwa et al., 2016; Wagstaff & Lindelow, 2010). The remaining threats are time-varying selection into reporting, omitted local shocks, spillovers, and crop-specific changes not fully captured by household-level controls. These threats are most concerning if they vary within households over time and are correlated with both prior season pest/disease reports and current season production choices after conditioning on the controls and wave effects. The main results are therefore interpreted alongside robustness checks varying the set of controls and considering samples with local pest/disease reports, and comparisons to other reported crop loss categories.

[8] Household and geographic controls include age, education, and sex of the household head, household size, distance to a paved road, annual mean rainfall, elevation, soil nutrient availability, and soil workability.

[9] I categorize crops as maize, hybrid maize, tobacco, groundnut, rice, beans, pigeon pea, potato, other grains, cotton, and all other crops based on the frequency with which these crops are reported in the sample.

[10] An instrumental variables strategy would require a source of variation that affects a household's reported pest/disease loss but does not otherwise affect its current season production choices. I do not observe objective pest or disease prevalence at the relevant spatial and temporal scale. A leave-one-out measure of other households' reports in the same enumeration area is not a valid instrument if neighbors' losses affect a household's decisions through information, beliefs, input markets, labor markets, or other local spillovers. I therefore use these local reports only as descriptive context and heterogeneity evidence, not as excluded instruments.

I focus on current season production decisions that households can plausibly adjust after a prior season reported loss. Pesticide and herbicide use are directly related to crop protection, although use is rare in this smallholder sample. Labor is a central input for all sample households, and many recommended practices for dealing with crop pests and diseases in Malawi, such as ploughing, intercropping, weeding, mulching, field monitoring, and removing pests by hand, involve increased labor inputs (MOA, 2017). I distinguish harvest and non-harvest labor because crop management responses should appear primarily in non-harvest labor, though the data do not identify pest-control labor specifically. These variables are measured in days per acre planted and are summed across labor sources. I also analyze seed expenditures because most households rely on saved seed and informal seed networks (Nordhagen & Pascual, 2013). Seed acquisition expenditures may reflect seed-stock replacement after crop losses, seed acquisition when saved seed is unavailable or judged unsuitable, or search for different seed types after a salient loss. The survey does not identify whether purchased seed is resistant or tolerant to pests or diseases.

Beyond these primary outcomes, I evaluate effects on fertilizer use, input expenditures, number of crops planted, area planted and crop diversity as measured by the Herfindahl index[11].

The main text focuses on production decisions and input responses. Appendix results report selected broader livelihood margins where they help interpret whether farm labor responses are accompanied by changes in *ganyu* (short-term rural labor, largely agricultural and often informal), wage work, or non-farm enterprise activity. I do not aim to identify welfare or food security effects.

5 Results

Table 2 presents the main household fixed-effects estimates. Each row reports the association between a prior season reported pest/disease preharvest loss and a current season agricultural decision. The table shows only the coefficient on the pest/disease loss variable, but all regressions include household and wave fixed effects, household and geographic controls, prior planting decisions, and other reported prior season losses.

Two results stand out. First, prior season pest/disease preharvest losses are associated with 489 MK more spending on seed acquisition per acre in the following season. This represents a 66% increase relative to the control mean of 738 MK (roughly USD 2.50). Given that many smallholder households in Malawi rely on saved seed and informal seed networks (Nordhagen & Pascual, 2013), this result suggests a meaningful change in seed acquisition after reported pest/disease losses. I further explore effects on seed sourcing in Table A3. The seed expenditure result is not matched by statistically significant reductions in saved seed use or saved seed shares. This suggests that inability to save output as seed stock does not drive the result. I also find no statistically significant shift between local or informal seed sources and formal or market sources. On the other hand, I do find effects on the location of seed acquisition: households reporting prior season pest/disease losses are 11.1 percentage points more likely to source seed from beyond the area near the village/community

[11] The Herfindahl index is calculated as the sum of squared shares of area planted across all crops. A larger Herfindahl index indicates lower crop diversity by planted acres.

Table 2: Effects of prior season agricultural shocks on current season agricultural decisions

	N	Control Mean (SD)	Prior season pest/disease (SE)
Used any pesticide or herbicide	3814	0.053	0.001
		[0.224]	(0.041)
Non-harvest labor days per acre	3814	81.095	20.855**
		[80.061]	(8.938)
Harvest labor days per acre	3814	20.726	3.513
		[22.810]	(2.313)
Used any organic fertilizer	3814	0.199	0.035
		[0.400]	(0.045)
Used any inorganic fertilizer	3814	0.808	0.018
		[0.394]	(0.040)
Seed acquisition expenditures per acre	3814	0.738	0.489***
(1000s MK)		[1.531]	(0.127)
Input and labor expenditures per acre	3814	7.231	1.441
(1000s MK)		[11.895]	(1.145)
Crop count	3814	2.637	-0.097
		[1.344]	(0.118)
Area planted (acres)	3814	2.731	-1.854
		[24.900]	(2.095)
Herfindahl index (planted acres)	3814	0.555	0.014
		[0.259]	(0.028)

Note: This table reports results from separate household fixed-effects regressions of current season agricultural outcomes on whether the household reported losing planted area to pests or diseases in the prior rainy season. Each row represents an outcome. Monetary values are in 2013 Malawian Kwacha. Control means are for households with no reported prior season pest/disease losses. All regressions include household and wave fixed effects, household and geographic controls, prior season planting controls, and controls for other preharvest and postharvest losses in the prior rainy season. Standard errors are clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

(the district/urban center or outside the district), relative to a control mean of 17.6%. Higher seed acquisition costs may therefore reflect increased transportation costs, which is included in reported seed expenditures. This suggests that the increase in seed spending is accompanied by changes in where households obtain seed, but the data do not include sufficient information to test whether households are purchasing different varieties, higher quality seed, or seed with pest or disease tolerance.

Second, households reporting a prior season pest/disease preharvest loss use 20.9 additional days of non-harvest labor per acre in the following season, a 26% increase relative to the control mean of 81.1 days. The coefficient on harvest labor is also positive, at 3.5 additional days per acre, but is not statistically significant in the main specification. The labor increase is concentrated in household rather than hired or free non-household labor, which account for just 3% of total non-harvest labor (Table A4). Household land preparation and planting labor increases by 12.5 days per acre relative to a control mean of 42.8 days (29%), and household weeding and fertilizing labor increases by 5.5 days per acre relative to a mean of 35.3 days (16%). Household harvest labor also increases by 4.6 days per acre, though this is marginally significant and is offset by small non-significant decreases in hired and free harvest labor. These results indicate that the main labor response comes from household labor applied to broad preharvest production tasks. The data do not break out pest or disease control labor, so I cannot identify the share of this increase in non-harvest labor allocated to these specific activities.

Other agricultural margins shown in Table 2 are not affected by prior season pest/disease losses. I find no increase in pesticide or herbicide use, consistent with low use of these inputs in the sample (5.3% of households).[12] The coefficients for organic fertilizer use, inorganic fertilizer use, total input and labor expenditures, crop count, area planted, and crop concentration (the Herfindahl index) are also not statistically significant. I also find generally non-significant effects on measures of non-farm household labor supply and non-farm enterprise engagement (Table A5). The estimated response is therefore not a broad shift across agricultural or livelihood decisions. It is concentrated in non-harvest labor and seed acquisition.

Table A5 reports additional current season crop and livelihood outcomes. Prior season pest/disease reports are not significantly associated with *ganyu* participation, *ganyu* hours, non-farm enterprise participation, enterprise hours, enterprise sales, or enterprise profits. The coefficient on wage labor participation is positive and marginally significant, but wage hours do not increase significantly. The results provide limited evidence that the farm labor response crowds out other observed work activities.

Table A7 compares the pest/disease results to associations between outcomes and other reported prior season crop loss categories, including drought, irregular rain or flooding, lack of labor, other preharvest losses[13], and postharvest losses. These other prior season shocks may affect households through similar channels as crop losses to pests or disease and are therefore useful for showing whether the main pattern is a generic response to any reported crop loss. The labor and seed pattern appears distinctive. Postharvest losses in the prior season have no effects on current season production decisions. Harvest losses due to drought and irregular rain or flooding are associated with lower seed expenditures in the following season, while irregular rain or flooding and lack of labor are associated with lower harvest labor and total input expenditures. Lack of labor in the prior season is also associated with lower current season non-harvest labor and pesticide/herbicide use. In general, these other forms of crop production shocks appear to decrease input spending or quantities in the following season, if they have any effect at all. By contrast, prior season pest/disease losses are associated with higher non-harvest labor and higher seed expenditures. This comparison validates presenting pest/disease reports separately as a distinct and important source of production risk rather than treating all crop loss categories as interchangeable.

The non-harvest labor and seed expenditure results are stable across various alternative specifications (Table A8). The estimates are nearly unchanged in a two-way fixed-effects specification without additional controls, when excluding controls for other reported losses, when adding prior season weather controls, when adding both prior and current season weather controls, and

[12] A 2017 Malawi Ministry of Agriculture Pest Management Plan indicates that herbicides, pesticides, and other chemicals are mainly used on cash crops such as tobacco, tea, sugarcane, coffee, and cotton, and that some maize farmers use insecticides (MOA, 2017). While the panel household sample in the Malawi IHPS survey includes one large-scale tobacco farmer cultivating over 300 acres, the largest cotton producer cultivates 4.5 acres and the largest sugarcane producer cultivates less than 1 acre, while coffee and tea are not asked about specifically but grouped under "other" crops, suggesting their production is not common in the sample. Thus the sample of primarily smallholder farmers in this survey likely does not include the farmers most likely to use pesticides/herbicides in Malawi, at the time of the survey, even if some maize farmers do use insecticides.

[13] Other reported causes of preharvest losses are animals, theft, fire, and "other".

when controlling for current season pest/disease reports. Increases in harvest labor days become marginally statistically significant in some specifications. The results are very similar when limiting the sample to households in enumeration areas where at least one sampled household ever reports a pest/disease loss, suggesting that the estimates are not driven by comparisons between communities with and without any sampled pest/disease reports. With enumeration area instead of district clustering of standard errors, the non-harvest labor remains significant only at the 10% level but the seed expenditure coefficient remains statistically significant at the 1% level. These checks suggest that the main labor and seed results are not driven by the particular control set, weather controls, or current season pest/disease crop losses.

6 Discussion

Taken together, the results show a concentrated pattern of adjustment after reported pest/disease losses. Households increase non-harvest labor and seed expenditures, with supporting evidence that the labor response comes mainly from household labor and that seed acquisition shifts toward sources farther outside the community. Other observed agricultural and livelihood margins show weaker or no systematic changes.

I now interpret this pattern in light of the conceptual framework in Section 2. The main question is which decision drivers change after a household reports a pest/disease loss. I first consider whether reported losses reduce resources available for next season production. I then discuss whether the evidence suggests they change what households know or believe about future pest/disease risk, the vulnerability of their own crops, or the returns to different management strategies.

The first channel is a resource channel. Reported pest/disease losses may reduce harvested output, cash income, seed retained from production, and the household's ability to finance next season inputs. If production responses were primarily driven by tighter cash constraints, one might expect reported losses to reduce prior season crop value and to reduce purchased inputs, especially among households with lower prior crop value or fewer liquidity buffers.

The main results in Table 2 provide limited support for this simple cash constraint interpretation. Total input and labor expenditures per acre do not fall after reported pest/disease losses, and the point estimate is positive. Seed acquisition expenditures increase, which is also not what one would expect if the dominant response were a broad reduction in purchased inputs. However, seed expenditures could reflect a different resource margin: households may need to replace seed stocks if pest/disease losses reduce the quantity or quality of grain available for seed retention.

The seed acquisition results help distinguish these possibilities. Table A3 shows no clear reductions in the use of seed saved from prior season production after reported pest/disease losses. This weakens a purely mechanical seed replacement interpretation. At the same time, households reporting prior season pest/disease losses are more likely to source seed from farther away, suggesting active search beyond the most local seed sources. Farmers in Malawi generally acquire new seed when the vigor of their stock decreases, when they want to grow new varieties, or when they lack their own saved seed (Nordhagen & Pascual, 2013). The Malawi Integrated Pest Management Plan also identifies certified seed and pest-tolerant varieties as recommended practices for some pests, diseases, and crops (MOA, 2017). The data do not identify seed traits or purchase motives, so I cannot show that households purchased certified, resistant, or tolerant seed. The effort to search for new seed sources may also reflect reduced local seed availability due to pest/disease damage in the community, though I find no decrease in the share of households obtaining seeds locally. Effects on seed expenditures therefore are more consistent with changes in seed search and acquisition than changes in household or local resources.

I next test whether the main labor and seed responses vary with observed prior season crop value. This test is useful because prior crop value is the closest observed proxy for the size of the production loss and for resources available after harvest. It is not a complete measure of liquidity, since it does not capture savings, credit access, informal transfers, in-kind constraints, input prices, or the timing of input purchases. I estimate a version of the main specification including prior season crop production value and its interaction with the prior season reported pest/disease loss indicator:

$$Y_{idt} = \alpha + \beta PDShock_{idt} + \psi PValue_{idt} + \phi(PDShock_{idt} \times PValue_{idt}) + H'_{idt}\theta + F'_{idt}\gamma + \tau_t + \mu_i + \epsilon_{idt}.$$

Here ψ captures the association between prior crop value and the current season outcome among households without a reported pest/disease loss, while ϕ asks whether the association between the reported loss and the outcome varies with prior crop production value.

The results in Table 3 provide little evidence that the main responses vary with prior crop value. Columns (2)-(6) show that the estimated associations with non-harvest labor and seed expenditures remain positive after adding prior crop value and its interaction with reported pest/disease loss. The interaction term is not statistically significant for non-harvest labor, harvest labor, seed expenditures, or total input and labor expenditures. The interaction is negative and statistically significant for pesticide/herbicide use, but pesticide/herbicide use is rare in the sample and is not a margin that moves in the main results.

Table 3: Effects of prior season pest/disease losses and value of crop production

	(1) Prior crop value	(2) Pesticide/ herbicide	(3) Non-harvest labor/acre	(4) Harvest labor/acre	(5) Seed acquisition expenditures/acre	(6) Input/labor expenditures/acre
Prior pest/disease crop loss	-1.803					
	(17.586)					
Prior pest/disease crop loss		0.046	21.848**	2.122	0.537**	2.441
		(0.042)	(10.526)	(2.351)	(0.196)	(1.526)
Prior crop production value (1000s MK)		-0.000	-0.032***	-0.006*	0.000	0.001
		(0.000)	(0.010)	(0.003)	(0.000)	(0.002)
Prior pest/disease loss x prior crop value		-0.000**	-0.010	0.013	-0.000	-0.010
		(0.000)	(0.030)	(0.014)	(0.001)	(0.010)
Observations	3814	3814	3814	3814	3814	3814
Baseline mean, no prior pest/disease loss	90.750	0.053	81.095	20.726	0.738	7.231

Note: The main independent variables are an indicator for whether the household reported losing planted area to pests or diseases in the prior rainy season, the value of crop production in the prior rainy season, and their interaction. Value of crop production is measured in 1000s of 2013 MK. Outcomes are measured in the current rainy season, except for the prior crop production value outcome. All regressions include household and wave fixed effects, household and geographic controls, prior rainy season planting controls, and controls for other reported preharvest and postharvest losses in the prior rainy season. Standard errors are clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The limited role of prior crop value in these results may partly reflect the nature of reported pest/disease losses, which appear less closely tied to measured production value than some other loss categories. Column (1) reports a negative but small and statistically insignificant association between a prior season reported pest/disease loss and prior crop production value when controlling for household fixed effects, household and geographic characteristics, and prior season planting decisions. I obtain similar null results when relating current season pest/disease reports to current season crop value. By contrast, prior season reported losses due to drought, irregular rains, and other preharvest causes are significantly associated with lower crop production value in that season (Table A6). While the data do not include information on the severity of preharvest crop losses, I find that pest/disease losses are typically reported to affect a smaller proportion of the total area planted by the household in a given wave than other types of shocks. This would be consistent with pests or diseases that affect only particular crops and plots whereas droughts, rains, or lack of labor shocks would apply across crops, and could explain why pest/disease shocks may have less of an effect on the value of crop production, especially after conditioning on area planted to different crops.

These results therefore weaken a simple explanation in which the main labor and seed responses are mechanically driven by reduced prior season crop production, but do not rule out all resource channels. Observed input expenditure is an imperfect test because households may maintain farm spending by reducing consumption or other expenditures, and constant nominal spending could still mask reduced real input use if prices rise or if households substitute across inputs. In addition, prior season crop production value is measured with error and is an imperfect proxy for liquidity at the time of current season input purchases, as it does not account for the role of savings, credit, informal transfers, and in-kind constraints. Taken together, however, the lack of evidence that pest/disease losses significantly decrease crop production value or reduce later input expenditures suggests that the main effects I estimate do not primarily reflect a tightening of the crop production budget.

The alternative channel emphasized in the framework is that a reported pest/disease loss changes perceived or known risk and the expected returns to different production strategies. A recent loss may reveal persistent local pest or disease pressure, crop susceptibility, or gaps in the household's mitigation capacity. It may also make pest and disease risk more salient even if objective risk has not changed. In either case, responses to changes in beliefs or perceptions about household crop production should be strongest after recent own losses, and may be weaker for older losses or for losses reported only by other households nearby.

The data are consistent with persistence in reported pest/disease losses. Prior season pest/disease reports are strongly predictive of current season pest/disease reports (Table A5). Households reporting a prior season pest/disease loss are 14.0 percentage points more likely to report a current season pest/disease loss, relative to a control mean of 5.5%. The same prior reports do not predict current season preharvest losses overall or current season non-pest/disease preharvest losses. This pattern suggests persistence or serial correlation in reported pest/disease losses, rather than a general increase in vulnerability to all reported crop loss categories.

The results on seed acquisition, with increased purchases and a greater likelihood of acquiring seed from farther away, could be consistent with changes in perception of the appropriateness of the current seed stock in the face of continued pest/disease risk. Similarly, increased household preharvest labor could reflect efforts to control or mitigate persistent risk. At the same time, the main labor and seed results are robust to controlling for current season pest/disease reports in Table A8, suggesting that they are not driven mechanically by continued pest/disease losses. But because the data only record crop pests/diseases when they cause the loss of some planted area that is reported by households, the effects I observe could still reflect persistent pest/disease pressure that does not cause reported losses. Indeed, the changes in production decisions could potentially help prevent such losses, though the data do not allow me to cleanly test that possibility.

I next examine whether current season production decisions are more strongly associated with recent own pest/disease reports than with older reports. This test is not intended to distinguish the resource channel from the risk perceptions and expectations channel, since both could generate stronger responses to recent losses. Instead, the test is informative because it asks whether effects persist across seasons, for example by having lasting effects on either production resources or on perceptions and expectations.

To construct a history of pest/disease reports, I focus on households observed in 2013 and combine their reports for the 2009, 2010, and 2012 rainy seasons. I estimate:

$$Y_{id,2013} = \alpha + \beta_{09} PDShock_{id,2009} + \beta_{10} PDShock_{id,2010} + \beta_{12} PDShock_{id,2012} + H'_{id}\theta + F'_{id}\gamma + \delta_d + \epsilon_{id}.$$

The outcomes are current season production decisions in 2013. The coefficients on the three pest/disease report indicators compare the association of current decisions with older and more recent own reports. Because this specification uses only the 2013 survey round, it cannot include household fixed effects. Instead, it includes district fixed effects and the same vector of household and geographic controls, prior rainy season planting controls, and controls for non-pest/disease prior season losses as in the main regressions.

Table 4: Reported pest/disease loss timing and current agricultural decisions

	(1) Pesticide/ herbicide	(2) Non-harvest labor/acre	(3) Harvest labor/acre	(4) Seed acquisition expenditures/acre
Own pest/disease report in 2009	0.023	-3.417	1.400	-0.247*
	(0.038)	(6.330)	(2.204)	(0.123)
Own pest/disease report in 2010	0.028	6.267	1.848	-0.201
	(0.031)	(8.034)	(1.747)	(0.188)
Own pest/disease report in 2012	0.022	30.988*	9.496*	0.571**
	(0.032)	(16.898)	(4.835)	(0.247)
Observations	1907	1907	1907	1907
p-value: 2012 = 2010	0.884	0.200	0.154	0.017
p-value: 2010 = 2009	0.885	0.375	0.862	0.857
p-value: 2012 = 2009	0.980	0.061	0.119	0.004

Note: Independent variables are indicators for whether the household reported losing planted area to pests or diseases in a particular rainy season. Data are not available on shock realizations in 2011. The sample is restricted to wave 2 households surveyed in 2013. All regressions include district fixed effects, household and geographic controls, prior rainy season planting controls, and controls for non-pest/disease prior season shocks. Standard errors are clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4 shows that the largest estimated associations for non-harvest labor, harvest labor, and seed expenditures in 2013 are attached to own pest/disease loss reports in 2012, the most recent observed prior rainy season. Households reporting pest/disease losses in 2012 increase non-harvest labor by 31.0 days, harvest labor by 9.5 days, and seed expenditures by 571 MK per acre in 2013. Reported pest/disease losses in 2009 or 2010 are not associated with significant increases in 2013, which is consistent with limited persistence of effects after controlling for whether such losses were reported in 2012. I can reject equality between the 2012 and older coefficients for seed expenditures, and can reject equality between 2012 and 2009 for non-harvest labor.

This timing pattern is informative because the framework predicts stronger responses when recent losses change perceived risk, reveal current vulnerability, or create immediate input needs. A pest/disease loss from the most recent season may be more relevant for current decisions because the same pest pressure, seed stock problem, crop susceptibility, or management gap is more likely to persist into the next season. Recent losses may also be more salient when households choose current inputs. Older losses, by contrast, may be less informative about current conditions, may already have prompted earlier adjustment, or may have affected crops and plots no longer central to the household's production choices. The timing evidence therefore supports an interpretation based on recent own experience (as in Freudenreich and Kebede, 2022), but it cannot distinguish objective persistence from salience or practical input timing.

If households are updating their risk perceptions and production expectations based on their own crop losses due to pests or disease, they might also respond to losses experienced by other community members. This is especially plausible in smallholder settings where neighboring households may grow similar crops, face similar weather, buy inputs from similar sources, and exchange information. While pest/disease reports are relatively rare at the household level, they are much more common at the community level (Table A2). Across seasons and waves, 3.8-8.1% of households report their own pest/disease loss while 29.2-47.0% of households reside in communities where at least one other sampled household reports such a loss. These patterns show that many households are locally exposed to reports of pest/disease losses even when they do not report losses themselves.

I test whether households respond mainly to own realized losses or also to reported losses among other sampled households in the same community, and find that effects on current season production decisions are most closely tied to own reported losses (Table A9). The presence of another local household reporting a prior season pest/disease loss has no significant effects on household pesticide/herbicide use, non-harvest labor, harvest labor, or seed expenditures. Interactions between own reports and other local reports are also not statistically significant.

The local report measures are imperfect because sampled neighbor reports may not capture what the household actually observed or learned, but the contrast between own and other reports indicates that households are not simply responding to general local pest/disease risk or realizations. This is consistent with the idea that own losses provide information that is difficult to infer from neighbors alone. Differences in production decisions and uncertainty about the extent to which others' experience may apply to them should both attenuate responses to losses by other community members. In contrast, the household learns about the vulnerability of its own crops, seed, plots, or management practices, or the loss becomes salient when it directly affected the household's production.

Finally, I conduct simple tests of whether responses to prior season pest/disease losses may vary based on measures of potential adjustment capacity. This matters because the framework predicts that responses to perceived risk should depend on access to resources, information, inputs, markets, and services. If households learn from a pest/disease loss but cannot access or afford alternative inputs, advice, or complementary services, observed production choices may change little.

Households with greater liquidity or access to resources may be better able to change production decisions, but I find no consistent evidence of significant differences in the effects of prior pest/disease losses on current production outcomes by indicators for loan access and for above median prior season crop production value, prior season planted area, and livestock holdings (Table A10). These proxies for current season household resource access are somewhat limited, and although the results suggest resource access is not a clear binding constraint on household responses they do not preclude a moderating effect of such access.

In contrast, I do find some significant differences by indicators of proximity to a road or market and access to extension, all of which may also affect households' interpretation of and ability to adjust to a prior season pest/disease loss. The results in Table A11 suggest that adjustment capacity is most relevant for labor responses. The interaction between prior pest/disease loss and being near a road is large, positive, and statistically significant for both non-harvest and harvest labor. Interactions with proximity to a daily market and pest-specific extension contact are also positive for both labor outcomes, although the daily market result is weaker for non-harvest labor. By contrast, seed expenditure interactions are less consistent. The interaction is positive and marginally significant for households near a road, but the other seed interactions are not statistically significant. I find little evidence that market or extension access changes pesticide/herbicide use or total input and labor expenditures.

One interpretation is that labor adjustments require information and complementary access even when they do not require large cash expenditures. Households closer to roads, markets, or pest-specific extension may be more likely to know which management practices to use, obtain complementary inputs, or reallocate labor toward crop management. Seed expenditures may be less strongly moderated by these variables because the response can occur through multiple channels: buying locally, traveling farther, replacing seed stocks, or changing seed sources. These heterogeneity results support the broader point that observed adjustment depends on household and community capacity, not only on the occurrence of a reported loss.

Overall, the mechanism evidence is more consistent with recent own pest/disease losses changing perceived risk, expected returns, or feasible production responses than with a simple crop budget tightening story. The main responses do not involve lower input spending, the crop value interactions are mostly insignificant, and the liquidity heterogeneity checks do not explain the labor and seed results. Resource constraints may still matter through seed stocks, in-kind constraints, or unobserved liquidity, but they do not appear to be the main explanation for the observed pattern.

The evidence instead points to targeted adjustment on flexible margins. Households increase household labor in broad crop management tasks and spend more on seed acquisition, especially after recent own losses. I find no such responses for other local reports of pest/disease losses alone, and the labor response appears stronger among households with better access to roads, markets, or pest-specific extension. The data cannot distinguish objective persistence in pest/disease pressure from salience or information about household-specific vulnerability. Still, the results show that reported pest/disease losses are followed by changes in margins smallholder households can plausibly adjust, especially household labor and seed acquisition, rather than broad reoptimization across all observed agricultural decisions.

7 Conclusion

This paper studies how smallholder households adjust production decisions after reporting pest/disease preharvest crop losses, and shows why pest and disease losses deserve more attention in research on agricultural risk and smallholder production decisions. Using the 2010 and 2013 Malawi IHPS household panel, I compare households to themselves across waves and estimate within-household associations between prior season reported pest/disease losses and next season input decisions. The central finding is that households reporting such losses increase non-harvest labor per acre and seed expenditures per acre in the following season. I do not find comparable increases in pesticide or herbicide use, fertilizer use, crop count, planted area, or crop concentration.

These findings suggest that pest/disease losses matter beyond the season in which damages occur. Households do not appear to respond through broad changes across all observed production decisions. Instead, they adjust on margins that are flexible and available in this setting: household labor and seed acquisition. The evidence that effects are driven by changes in available crop production resources is weak, since the main responses do not involve lower input spending and are not explained by observed prior crop production value. The results are more consistent with recent own losses changing perceived risk, expected returns, or practical input needs, although the data cannot distinguish these channels cleanly.

Several limitations remain central. The treatment is a household report of realized preharvest crop-area loss attributed to insects or diseases, not objective pest or disease prevalence. The survey does not identify the biological stressor, the full severity of loss, direct pest-control labor, seed traits, purchase motives, productivity protection, or welfare effects. Household fixed effects address time-invariant selection into which households report pest/disease losses but cannot eliminate endogenous reporting, unobserved time-varying shocks, local equilibrium effects, or changes in household vulnerability.

Future work with longer panels, objective pest and disease measures, richer liquidity and asset data, direct task-use measures, and seed-trait information could address these limitations and allow more direct tests of mechanisms. A particularly important question is whether the additional labor and seed expenditures documented here help households prevent future crop losses, protect production, or improve welfare, or instead represent costly coping with persistent risk. Measuring those follow-on adjustments is important to determine whether and how the costs of pest and disease losses may extend beyond the output lost in the affected season.

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A Appendix

Table A1: Household summary statistics, by household report of prior season pest/disease shock

	No prior pest/disease loss (SD)	Prior pest/ disease loss difference (SE)
Household characteristics		
Age of household head	45.548	-1.889
	(16.227)	(1.166)
Education of household head (years)	5.144	0.854**
	(4.110)	(0.336)
Male household head	0.761	-0.005
	(0.427)	(0.038)
Number of household members	5.301	0.206
	(2.347)	(0.132)
Number of plots	2.191	0.362***
	(1.139)	(0.102)
Distance to nearest road (km)	9.482	-1.326
	(9.601)	(0.869)
Avg 12-month total rainfall(mm) for	849.290	6.760
July-June	(90.983)	(6.765)
Elevation (m)	910.343	-37.930
	(326.785)	(40.219)
Nutrient availability	1.690	0.019
	(1.264)	(0.192)
Workability (constraining field management)	1.890	0.253
	(1.309)	(0.172)
Prior season crop production		
Crop count	2.167	0.527***
	(1.111)	(0.119)
Area planted (acres)	2.498	0.069
	(7.374)	(0.227)
Maize acres planted	0.922	-0.275*
	(6.735)	(0.143)
Cotton acres planted	0.059	0.182*
	(0.508)	(0.095)
Preharvest crop loss not due to	0.349	0.203***
pests/diseases	(0.477)	(0.043)
Any postharvest crop loss	0.148	0.259***
	(0.355)	(0.058)
Crop production value (1000s MK)	90.750	8.346
	(167.617)	(12.635)

Note: This table shows the control mean and difference by exposure to pest/disease shocks for selected community and household characteristics from a series of separate regressions. For nutrient availability and soil workability constraints, 1=no/slight, 2=moderate, 3=severe. *p<.10, **p<.05, ***p<.01.

Table A2: Local presence of sampled pest/disease loss reports

	Wave 1 prior	Wave 1 current	Wave 2 prior	Wave 2 current
Own household report	3.9	3.9	3.8	8.1
Any HH report in EA	32.0	31.4	30.9	49.0
Any other HH report in EA	30.5	29.7	29.2	47.0
Mean HH reports among reporting EAs	1.48	1.51	1.49	1.94

Note: This table reports the share of households with own pest/disease reports and the share located in enumeration areas/communities where at least one sampled household, or at least one other sampled household, reports pest/disease losses. Values are percentages except for the mean number of reports among reporting enumeration areas. These measures are based on sampled household reports and should not be interpreted as objective pest/disease prevalence.

Table A3: Seed acquisition and source outcomes

	N	Control Mean (SD)	Prior season pest/disease (SE)
Saved seed	3814	0.658	-0.025
		[0.475]	(0.047)
Saved-seed share	3354	0.095	0.010
		[0.170]	(0.023)
Seed source: local/informal	3814	0.923	0.031
		[0.267]	(0.030)
Seed source: formal/market	3814	0.606	0.021
		[0.489]	(0.055)
Seed source location: village/nearby	3814	0.969	-0.028
		[0.174]	(0.018)
Seed source location: farther away	3814	0.176	0.111**
		[0.381]	(0.051)

Note: This table reports seed acquisition, seed source, and seed-source location outcomes. Saved seed outcomes refer to seed retained from prior production, while seed source and location outcomes describe seed acquisition for the current season. Some households do not report the share of saved seed. The table provides context for interpreting the seed-expenditure response, but the survey does not identify seed traits, seed quality, or whether purchased seed is resistant or tolerant to pests or diseases. Standard errors are clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A4: Crop labor response by labor source and task

	N	Control Mean (SD)	Prior season pest/disease (SE)
HH land prep/planting labor days per acre	3814	42.779	12.485**
		[46.625]	(6.060)
HH weeding/fertilizing labor days per acre	3814	35.264	5.529*
		[37.248]	(2.968)
Hired non-harvest labor days per acre	3814	2.080	1.211*
		[5.362]	(0.732)
Free non-harvest labor days per acre	3814	0.364	0.257*
		[1.556]	(0.149)
HH harvest labor days per acre	3814	19.858	4.642*
		[24.522]	(2.505)
Hired harvest labor days per acre	3814	0.636	-0.087
		[2.032]	(0.188)
Free harvest labor days per acre	3814	0.614	-0.102
		[1.881]	(0.203)

Note: This table decomposes the crop-labor response by labor source and broad task category. Outcomes are labor days per acre. The table distinguishes household, hired, and free labor, and land preparation/planting, weeding/fertilizing, and harvest tasks. It does not identify whether labor is specifically used for pest or disease control. Standard errors are clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A5: Effects of prior season agricultural shocks on current season crop losses and household non-farm livelihood engagement

	N	Control Mean (SD)	Prior season pest/disease (SE)
Current pest/disease preharvest crop loss	3814	0.055	0.140***
		[0.228]	(0.032)
Current any preharvest crop loss	3814	0.593	0.017
		[0.491]	(0.046)
Current non-PD preharvest crop loss	3814	0.551	-0.036
		[0.497]	(0.058)
Any ganyu labor	3814	0.440	0.040
		[0.497]	(0.050)
Ganyu hours per adult equivalent	3814	65.482	2.798
		[131.745]	(21.692)
Any wage labor	3814	0.172	0.063*
		[0.377]	(0.033)
Wage hours per adult equivalent	3814	63.240	20.228
		[216.739]	(18.324)
Any non-farm enterprise	3814	0.231	0.005
		[0.422]	(0.042)
Enterprise hours per adult equivalent	3814	146.904	66.245
		[729.703]	(158.355)
Enterprise sales in last month (1000s MK)	3814	8.542	-8.362
		[43.637]	(6.315)
Enterprise profit in last month (1000s MK)	3814	3.068	-2.971
		[13.719]	(2.071)

Note: This table reports separate household fixed-effects regressions of current season reported crop loss outcomes and broader labor/livelihood outcomes on whether the household reported a prior season pest/disease loss. The current reported-loss rows provide context on serial correlation in reported losses. Ganyu and wage hours are last-12-month totals per adult equivalent; enterprise sales and profit are last-month measures. Monetary values are in Malawian Kwacha. Control means are for households with no reported pest/disease-related losses. All regressions include household and wave fixed effects, household and geographic controls, controls for previous rainy season planting decisions, and controls for other preharvest and postharvest losses in the previous rainy season. Standard errors are clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A6: Reported preharvest losses and crop production value

	(1) Prior season losses, prior crop value	(2) Current season losses, current crop value
Pest/disease preharvest crop loss	-1.803	-3.080
	(17.586)	(28.013)
Drought preharvest crop loss	-20.650*	-14.823
	(10.562)	(33.427)
Irregular rain/flooding preharvest crop loss	-20.141**	-9.213
	(8.591)	(28.055)
Labor-shortage preharvest crop loss	-11.838	-55.613*
	(12.290)	(29.144)
Other preharvest crop loss	-18.540**	-6.314
	(7.190)	(15.666)
Observations	3814	3814

Note: Column (1) reports associations between prior season reported preharvest loss categories and prior season crop production value. Column (2) reports associations between current season reported preharvest loss categories and current season crop production value. Crop production value is measured in 1000s of 2013 MK. All regressions include household and wave fixed effects, household and geographic controls, season-matched planting controls, and the relevant postharvest loss control. Standard errors are clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A7: Comparison to other reported prior season crop loss shocks

	(1) Pest/disease (SE)	(2) Drought (SE)	(3) Irregular rains/ flooding (SE)	(4) Lack of labor (SE)	(5) Other preharvest crop shock (SE)	(6) Any postharvest crop loss (SE)
Used any pesticide or herbicide	0.001	0.009	-0.014	-0.043**	-0.017	0.007
	(0.041)	(0.016)	(0.015)	(0.021)	(0.013)	(0.013)
Non-harvest labor days per acre	20.855**	8.285	-3.616	-23.739***	6.558	4.645
	(8.938)	(7.739)	(6.423)	(9.140)	(4.584)	(5.974)
Harvest labor days per acre	3.513	-1.443	-2.663*	-2.915*	0.264	1.741
	(2.313)	(1.624)	(1.446)	(1.676)	(1.410)	(1.335)
Used any organic fertilizer	0.035	0.018	0.017	-0.034	-0.020	0.023
	(0.045)	(0.026)	(0.024)	(0.040)	(0.023)	(0.024)
Used any inorganic fertilizer	0.018	-0.018	-0.017	-0.038	-0.007	0.014
	(0.040)	(0.023)	(0.023)	(0.044)	(0.019)	(0.018)
Seed acquisition expenditures per acre	0.489***	-0.200**	-0.208***	-0.013	0.029	-0.036
(1000s MK)	(0.127)	(0.088)	(0.073)	(0.144)	(0.090)	(0.088)
Input and labor expenditures per acre	1.441	-0.885	-1.436**	-1.692***	-0.573	0.946
(1000s MK)	(1.145)	(0.691)	(0.656)	(0.581)	(0.634)	(0.617)
Crop count	-0.097	-0.028	0.041	-0.052	0.090	0.056
	(0.118)	(0.101)	(0.061)	(0.123)	(0.083)	(0.090)
Area planted (acres)	-1.854	-0.856	0.952	0.192	-4.019	-0.322
	(2.095)	(0.577)	(0.657)	(0.367)	(2.708)	(0.943)
Herfindahl index (planted acres)	0.014	0.004	-0.015	0.009	-0.032**	-0.005
	(0.028)	(0.018)	(0.016)	(0.021)	(0.014)	(0.019)

Note: This table reports coefficients from household fixed-effects regressions that compare prior season pest/disease loss reports with other reported prior season crop loss categories. Each row is a current season agricultural outcome. All specifications include household and wave fixed effects, household and geographic controls, prior season planting controls, and the relevant set of other prior season reported loss controls. Standard errors are clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A8: Robustness by specification

	(1) Baseline	(2) TWFE only	(3) No other loss controls	(4) Prior weather	(5) Prior + current weather	(6) Current PD control	(7) Ever PD EA sample	(8) EA clustering
Used any pesticide or herbicide	0.001	0.008	-0.001	-0.002	-0.001	0.001	-0.001	0.001
	(0.041)	(0.047)	(0.042)	(0.042)	(0.042)	(0.041)	(0.041)	(0.034)
Non-harvest labor days per acre	20.855**	21.308**	20.534**	19.674**	20.158**	20.644**	21.037**	20.855*
	(8.938)	(9.540)	(9.319)	(8.895)	(9.117)	(8.847)	(8.844)	(11.236)
Harvest labor days per acre	3.513	4.603**	3.687*	3.749	4.085*	3.723	4.099*	3.513
	(2.313)	(2.170)	(2.156)	(2.296)	(2.243)	(2.273)	(2.199)	(2.713)
Seed acquisition expenditures per acre	0.489***	0.499***	0.480***	0.484***	0.497***	0.502***	0.478***	0.489***
(1000s MK)	(0.127)	(0.130)	(0.126)	(0.130)	(0.137)	(0.127)	(0.128)	(0.187)
Input and labor expenditures per acre	1.441	1.541	1.515	1.461	1.464	1.496	1.392	1.441
(1000s MK)	(1.145)	(1.168)	(1.133)	(1.142)	(1.156)	(1.141)	(1.148)	(1.234)

Note: This table reports robustness checks for the main household fixed-effects specification. Columns compare the baseline estimate to two-way fixed effects without additional controls, a specification without other reported loss controls, specifications adding prior season weather controls and both prior and current season weather controls, a specification controlling for current season pest/disease-related loss reports, a sample restricted to enumeration areas with any pest/disease-related report, and standard errors clustered at the enumeration-area level. Standard errors are clustered at the district level unless otherwise specified. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A9: Own and local pest/disease report experience

	(1) Pesticide/ herbicide	(2) Non-harvest labor/acre	(3) Harvest labor/acre	(4) Seed acquisition expenditures/acre
Own prior pest/disease crop loss	-0.028	14.187	1.675	0.522**
	(0.047)	(14.672)	(3.597)	(0.209)
Other EA household reports prior pest/disease loss	-0.015	0.456	1.330	-0.029
	(0.012)	(6.258)	(1.229)	(0.090)
Own loss x other-EA report	0.057	12.358	3.111	-0.048
	(0.065)	(21.257)	(6.291)	(0.313)
Mean of dep. var.	0.057	81.740	20.902	0.749
Observations	3796	3796	3796	3796

Note: This table reports household fixed-effects regressions that include indicators for own prior pest/disease losses, other sampled household pest/disease reports in the enumeration area, and their interaction. Outcomes are measured in the current rainy season. All regressions include household and wave fixed effects, household and geographic controls, prior rainy season planting controls, and controls for other reported preharvest and postharvest losses in the prior rainy season. Standard errors are clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A10: Heterogeneity by indicators of potential household liquidity

Outcome	(1) PD loss × high prior crop value	(2) PD loss × high livestock	(3) PD loss × any loan	(4) PD loss × high prior planted area
Used any pesticide or herbicide	0.026	-0.019	0.161***	-0.082
	(0.072)	(0.059)	(0.056)	(0.063)
Non-harvest labor days per acre	1.109	-5.528	14.142	-8.665
	(14.489)	(11.564)	(20.025)	(16.025)
Harvest labor days per acre	5.253	4.818	-0.060	-3.283
	(4.107)	(4.179)	(6.181)	(5.162)
Seed acquisition expenditures per acre (1000s MK)	0.296	-0.185	0.152	-0.663
	(0.376)	(0.279)	(0.321)	(0.399)
Input and labor expenditures per acre (1000s MK)	5.041*	-2.040	-0.326	2.380
	(2.603)	(2.082)	(2.591)	(2.635)

Note: This table reports interaction estimates between prior season pest/disease loss reports and proxy measures of potential household liquidity, measured as indicator terms where 'high' indicates above median values. Each cell reports the interaction coefficient from a separate regression. All regressions also include the main prior pest/disease loss indicator, the heterogeneity variable, household and wave fixed effects, household and geographic controls, prior rainy season planting controls, and controls for other reported preharvest and postharvest losses in the prior rainy season. Interaction estimates should be interpreted as suggestive heterogeneity checks. Standard errors are clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A11: Heterogeneity by market access and extension contact

Outcome	(1) PD loss × near road	(2) PD loss × near daily market	(3) PD loss × any extension	(4) PD loss × pest extension
Used any pesticide or herbicide	-0.020	-0.032	0.028	0.024
	(0.065)	(0.070)	(0.091)	(0.098)
Non-harvest labor days per acre	46.564***	42.135*	17.494	39.671**
	(14.958)	(24.234)	(14.826)	(17.579)
Harvest labor days per acre	11.423**	10.183*	4.679	13.071**
	(4.858)	(5.643)	(5.054)	(4.794)
Seed acquisition expenditures per acre (1000s MK)	0.839*	0.489	0.289	0.522
	(0.419)	(0.360)	(0.359)	(0.421)
Input and labor expenditures per acre (1000s MK)	1.417	-0.156	-0.072	0.849
	(1.387)	(2.033)	(2.291)	(2.830)

Note: This table reports interaction estimates between prior season pest/disease loss reports and measures of road access, daily-market access, any extension contact, and pest-specific extension contact. Each cell reports the interaction coefficient from a separate regression. All regressions also include the main prior pest/disease loss indicator, the heterogeneity variable, household and wave fixed effects, household and geographic controls, prior rainy season planting controls, and controls for other reported preharvest and postharvest losses in the prior rainy season. Interaction estimates should be interpreted as suggestive heterogeneity checks. Standard errors are clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.