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Impact of seed system interventions on food and nutrition security in low- and middle-income countries: A scoping review

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ABSTRACT

The role of seed systems in nutrition of smallholder farmers has received little attention. This review mapped evidence of impact on nutrition, identifying themes from 43 studies as direct seed supply, improving seed access, and adoption of improved seed. Results had more positive than mixed/negative impacts on food security, household resilience, dietary quality, and diversity and/or nutrition status. Studies were skewed towards cereals and improved seed compared to other species and traditional/indigenous seed, and geared towards seed rather than the seed system. While most evaluated seed adoption and impact, few reported strategies for sustainable inclusion into farmer seed systems. Enabling factors contributing to positive nutrition impact included use of multi-component interventions and gender-sensitive and participatory approaches that consider the contexts.

1. Introduction

Food and nutrition security is a key development indicator important for good health, growth and development of children; it reduces child mortality and contributes to cognitive development and productivity of a population (Bhutta et al., 2013). Despite decades of global efforts to tackle malnutrition, hunger is on the rise and has been exacerbated by the COVID-19 pandemic. Current estimates state that about 720–811 million (9–10%) face hunger and 2.37 billion people are facing moderate or severe food insecurity (30.4%), with the majority in Asia and Africa (FAO et al., 2021). Agriculture is one of the sectors through which nutrition-specific and nutrition-sensitive interventions[1] can improve nutrition and health.

The potential of agriculture to contribute directly to nutrition especially for the most food insecure is large and widely acknowledged, primarily through improving diet quality (agriculture to nutrition pathways) (Herforth and Harris, 2014; Ruel et al., 2013; World Bank, 2007). Enhancing access to and utilization of good quality seed is widely considered essential to agricultural production (Almekinders et al., 2019; McGuire and Sperling, 2013). However, agricultural interventions that promote the production and consumption of nutritious foods often lack details on the seeds and other agriculture inputs. As such, there is limited evidence on the extent to which seeds and seed systems directly (or indirectly) contribute to improving diet quality and nutrition outcomes.

Seed systems refer to a range of technologies, organizational set-ups, and market and non-market institutions through which seeds are accessed and used (McGuire and Sperling, 2013). Smallholder farmers access seeds through both informal and formal seed systems (Louwaars and de Boef, 2012). In the informal seed systems, farmers conduct seed production, selection and storage and use their own saved seed or access seed through informal networks where seed is exchanged, received as gift, bartered, or purchased from local markets. Key informal seed system challenges include low germination and vigor, disease

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[1] Nutrition-specific interventions address the immediate determinants of undernutrition, like inadequate food and nutrient intake, suboptimal care and feeding practices, and poor health. Nutrition-sensitive programs address the underlying causes of undernutrition, including poverty, food insecurity, poor maternal health, education, social status or empowerment and limited access to water, sanitation, hygiene, and health services (Leroy et al., 2016).

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contamination and build-up and inadequate quantity and diversity of seed (Louwaars and de Boef, 2012). The formal seed system is guided by plant breeding and multiplication methodologies mainly used by the public or private sector and formal regulation, certification, and laws. Key formal seed system challenges include poorly developed seed value chains for example inadequate breeding, production or delivery (Louwaars and de Boef, 2012). Both the formal and informal systems are important for smallholder farmers and have complementarities (Almekinders et al., 2019; Buddenhagen et al., 2017). The specific system(s) used depend on the crop, varietal characteristics, seed accessibility, price and quality and market value of produce (Hoogendoorn et al., 2018).

Given that timely and sufficient access to quality and preferred seed are major challenges particularly in low and middle income countries, seed system development investments have included: breeding for improved varieties, increasing market supply of quality seeds, soil health and fertility management to improve seed quality, development of infrastructure, capacity strengthening across the seed value chain, enhancing access to finance to support farmer access to seed and investment in seed technologies, and improvement of policy and regulatory frameworks (AGRA, 2018; Eriksson et al., 2018; Hoogendoorn et al., 2018; Walker and Alwang, 2015). Some interventions have included nutrition-sensitive elements and report varied nutrition impact (positive, mixed or weak) on production, consumption and income (Pandey et al., 2016; World Bank, 2007). Despite investments and progress, weak links between agricultural production and nutrition and an incomplete understanding of the role of seed systems in supporting household nutrition remain. For example, between enhanced seed access and impact on farm household nutrition, lie several household decisions and practices, plus different barriers and enablers (Dixon et al., 2007; Kanter et al., 2015; Nabuuma et al., 2020). The gaps in evidence affects the scaling and impact of interventions. Little attention has been given to the role of seed systems, seed interventions and seed diversity in the nutrition of smallholder farmers. A potential danger is that introduction of novel, more nutritious, species or cultivars without embedding in existing functional seed systems does not sustain beyond the intervention period (Lammerts van Bueren et al., 2018).

This scoping review aimed at mapping the available evidence for the impact of seed system-oriented interventions on nutrition outcomes and the enabling and inhibiting environment in low- and middle-income countries. The evidence will be used to inform the impact pathways between seed interventions and design of seed interventions.

2. Methodology

The review was in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018) and the methodology of the Joanna Briggs Institute (JBI) Reviewer's Manual for scoping reviews (Peters et al., 2017). Studies were considered for inclusion when the predefined PCC (Population, Concept and Context) criteria were fulfilled (Table 1).

Nutrition-related outcomes considered in the review included both intermediate and final outcomes. i) food security, ii) household resilience, iii) dietary quality and diversity and iv) nutrition status. The following definitions were used:

i. Food security is defined as "a condition when all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (CFS, 2012). Studies had a food security outcome when they assessed and/or linked changes in food availability, food access, food utilization, food security, or income.

ii. Household resilience is defined as "the ability of a household to maintain a certain level of well-being, that is being food secure by withstanding shocks and stresses", which is dependent on the available livelihood options and ability to handle risks (FAO, 2010). Studies had a household resilience outcome when they assessed or linked: change in income, poverty, consumption expenditure, calorie intake, off-farm self-employment/wages, yield/harvest, welfare, labor, livelihood, tolerance against weather variability or projected climate change and other natural hazards, self-sufficiency, or seasonal food scarcity to household wellbeing and food security.

iii. Dietary quality and diversity, where diet quality is an umbrella term, not precisely defined but generally describes how well an individual's diet conforms to dietary recommendations (Alkerwi, 2014). A high-quality diet is one that includes a diversity of foods that are safe and provide levels of energy, proteins and essential micronutrients appropriate to age, sex, disease status and physical activity (Global Panel, 2016). Dietary diversity refers to the number of food groups consumed over a given period and reflects the nutrient adequacy of the diet (Kennedy et al., 2013). Studies had a dietary quality and diversity outcome when they assessed changes in dietary diversity, dietary intake patterns, micronutrient consumption, food provisioning habits, quantity of consumption, or nutrient yields.

iv. Nutrition status assessment involves interpretation of information from dietary, laboratory, anthropometric and clinical studies

Table 1
Scoping review inclusion and exclusion criteria.

	Inclusion criteria	Exclusion criteria
Population	All humans (any age, sex, with any disease, pregnancy, breastfeeding, etc.)	Plants, plant diseases Livestock, aquaculture Cell culture Human genetics
Concept		
Nutrition	Anthropometry Infant and young child feeding Knowledge and practices (KAP) Diet/dietary diversity Macro/-micronutrient intake Food security Household resilience Income	Health outcomes not directly related to nutrition Food safety
Seed system-based interventions	Food crop seed systems at farmer, community, regional or national level	Non-food seed systems (cotton, sugar cane) Agricultural production of vegetables or other food (that paid no attention to aspects of seed/starting material) Seeds for animal feed Any plant or seed outcomes as final outcome (e.g., nutritional value of seeds)
	Interventions along the seed value chain • Improved seeds/GMO, plant breeding, varieties, cultivars, planting material, landraces • Ex situ conservation • Policies Hypothesized connections	No clear connection between seed system interventions and nutrition/HH outcomes Agricultural management practices to increase crop yield without a combination with seeds. • Fertilization; Pesticides • Irrigation • Intercropping • Technology • conservation agriculture (CA) based crop management practices, tillage
Context		
Country	Low- and middle-income countries	High income countries
Publication type	Any existing literature: primary, secondary, meta-analysis, qualitative studies;	Conference papers, Missing abstracts, Reviews Published before 1999
Language	English	Other

to determine the changes in nutrition status of individuals and populations as influenced by nutrient intake and utilization (Gibson, 2005). Studies had a nutritional status outcome if they assessed nutritional status, micronutrient status, or anthropometric measurements.

While food security and household resilience are technically not nutrition indicators, they were considered as such based on theoretical impact pathways that elaborate how changes in seed systems can translate into food and nutrition security and thus impact nutrition (Nabuuma et al., 2020). Like the agriculture to nutrition pathways, the seed to nutrition pathways contribute to nutrition primarily through improving diet quality a nutrition indicator that is critical to contributing to good nutrition status and health (Herforth and Harris, 2014). Studies had the underlying assumption that increasing food production would allow access to more nutritious food through a combination of consumption of produce and use of income from sales. Increasing production of nutrient dense species or cultivars more explicitly focused on consumption of produce.

Seed referred to agricultural seed and/or planting material for food crops at farmer, community, company, or national level. The context was limited to low- and middle-income countries given the predominance of smallholder farms, vulnerability to shocks and stresses, and malnutrition. All study types, cited in the electronic databases PubMed, Web of Science and AGRIS by the search date (24-09-2019) and published in the English language were considered.

The search strategy included two search blocks. The first search block covered the seed system with the terms: seed, plant genetic resource* (PGR), plant breeding, crop breeding, planting material. The second block covered the effects on nutrition with the terms: food quantity, food security, food quality, food diversity, food variety, food access, food biodiversity, food sovereignty, diet* security, diet* quality, diet* diversity, diet* variety, diet* access, nutrition* security, nutrition* quality, nutrition* diversity, nutrition* variety, nutrition* status, nutrition* intake, climate resilience, household resilience. Each combination of words between commas was treated as single search term and the exact formulation varied with the database syntax. Single search terms within one block were linked with the Boolean Operator "OR" and the two blocks were further linked with "AND", the asterisk (*) was used as wildcard to search for a word root. The searching option "all fields" was used for each database. The reviewing process was conducted independently by two authors (CR, HTK) and discrepancies resolved through discussion or by a third author (JR).

Identified studies were exported into the literature management program Mendeley®. A data-charting form was developed in Microsoft excel. At the start, data from 10 papers was extracted independently and compared to unify the charting process. Data charting was then conducted independently and concurrently, followed by detailed cross-checking. Data was extracted for analysis by two authors (CR, DN).

2.1. Analyzed studies

The initial database search identified 7555 studies, duplicates removed, and studies screened based on the criteria (Table 1). Eighty-four studies were eligible for charting (Fig. 1), during which, five studies were identified through searching reference lists and 46 studies were excluded due to duplicate articles, type of study method and reporting of outcome(s), and study types that did not correspond to the inclusion criteria.

Forty three relevant studies were retained and grouped according to the nature of the seed intervention that was implemented or modelled to assess the potential effect on nutrition outcomes, 1) a direct change in seed availability through supply of seed, 2) indirect ways of changing seed supply, so making the seed supply system provide different seed for the duration of the intervention or 3) effects of adoption of novel seeds that were previously released or promoted. The majority of studies (32)

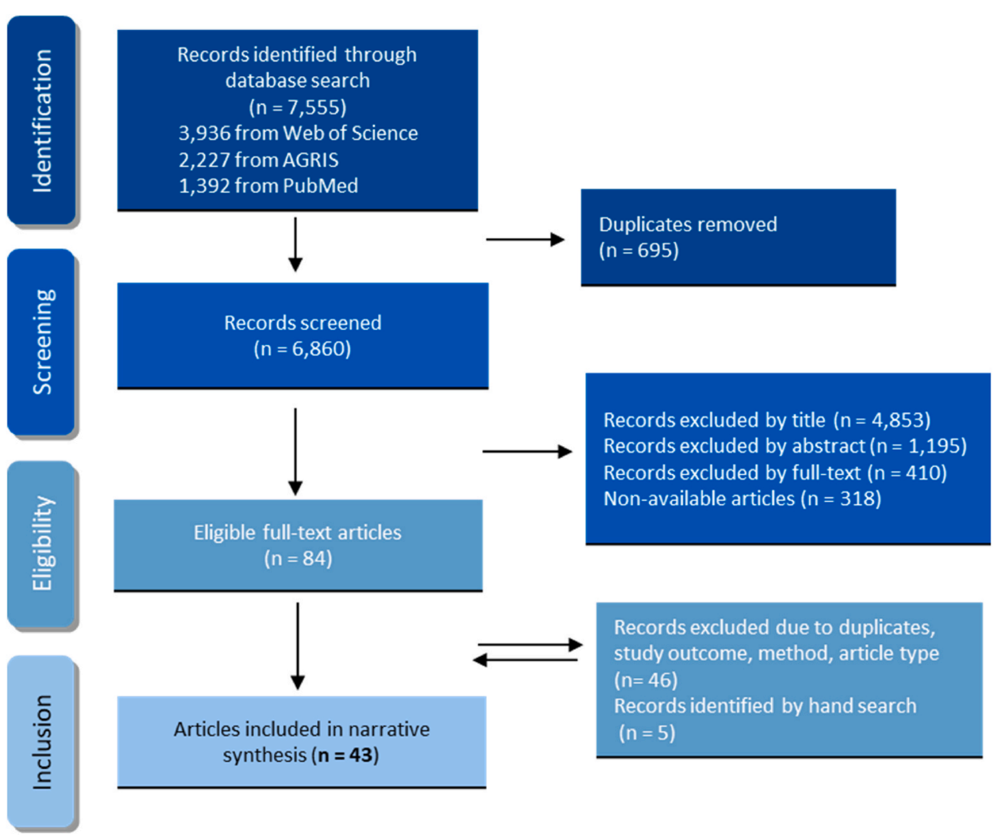

Fig. 1. Flow chart of the scoping literature search according to the PRISMA statement.

used quantitative methods, an additional nine used mixed methods, and two used qualitative methods.

3. Results

Three themes of seed intervention were noted, direct supply/provision of seed (13 studies), improving farmer access to seed in ways other than directly supplying seed (14 studies), and actual adoption of improved seed and other technologies (16 studies) (Table 2). The third category included a combination of studies that did not have a typical seed intervention but assessed impact of seed previously released or promoted on nutrition. Other areas of focus were: 1) increasing crop yield and productivity (28 studies), 2) promotion or evaluation of nutrient dense varieties (8 studies), and 3) increasing seed diversity (3 studies), 4) increasing seed access and income through seed enterprises (2 studies), and 5) improving seed access following a shock (seed security, 3 studies).

Most studies (26) were on cereals, where 17 studies focused on only cereals and nine focused on a combination of cereals and other food items like legumes, tubers, and vegetables. Two studies investigated only vegetables and two investigated only legumes (Table 2).

The target seed(s) were mainly improved as only two studies included seed for traditional or indigenous varieties (unimproved).

Table 2
Key characteristics of the 43 studies included in this scoping review (Figures following characteristic refer to number of studies included in the review).

Characteristic	Distribution of studies
Region	Africa 33; Asia 9 Developing countries 1
Nature of seed intervention studied [a]	Direct supply of seeds 13; Improve seed access 14 Effects of adoption of improved seeds [b] 16
Strategy of intervention and nature of study [a]	Improve food availability and/or diversity thus enhancing consumption and nutrition: Direct supply of seeds 8; Improve seed access 2; Effects of adoption of improved seed and technologies 2 Improve productivity and income thus enhancing food access and nutrition: Direct supply of seeds 5; Improve seed access 12; Effects of adoption of improved seed and technologies 14
Areas of focus [a]	Crop productivity 28; Nutrient dense varieties 8 Seed diversity 3; Seed security 3; Seed enterprises [c] 2
Food crop	General 7 (no food item specified) Cereals only 17; Cereals & legumes 4 Cereals, legumes & tubers or vegetables or oil seeds 3 Cereals & tubers 1; Cereals, legumes, tubers & vegetables 1 Tubers 3; Vegetables 2; Legumes 2 Vegetables, tubers, legumes & fruits 1; Vegetables & oil seeds 1 Fruits & vegetables 1
Type/trait of seed	Improved not specified 12; High yielding 10 Resistant to biotic and/or abiotic stress 5; Biofortified 5 Resistant to biotic and/or abiotic stress & high yielding or early maturing or biofortified 5; Early maturing & traditional or indigenous 1 Both indigenous & improved seeds 4; Traditional or indigenous 1
Nutrition outcome [d]	Food security 26; Household resilience 14 Dietary quality and diversity 11; Nutrition status 3

[a] One study was in more than one category.
[b] A combination of studies that did not themselves carry out a typical seed intervention but rather assessed the impact of improved seed previously released or promoted or modelling studies that assumed adoption had succeeded.
[c] To increase income through seed production as an area of focus is referred to as seed enterprises in the rest of the paper.
[d] Some studies reported more than one nutrition outcome.

While 12 studies did not specify the type of improvement, 26 studies specified the improved traits and these included high yielding seed, biofortified seed, early maturing seed, and seed that was resistant to biotic and/or abiotic stress or a combination of these. Seed resistant to biotic and/or abiotic stress included varieties that were improved for drought resistance, pest and disease resistance, salinity, or climate change adaptation.

Food security was the most assessed nutrition outcome with 17 studies assessing only food security, and nine studies assessing food security together with other nutrition outcomes, either household resilience (6), or dietary quality and diversity (2), or all three outcomes (1). Followed by household resilience in a total of 16 studies. Eleven studies evaluated dietary quality and diversity with four studies assessing only dietary quality and diversity and seven assessing dietary quality and diversity alongside other outcomes. Only three studies assessed the impact on nutrition status, that is, child anthropometric measurements (height-for age, weight-for-age, weight-for-height Z-scores) and one study on vitamin A status (serum retinol).

Several indicators were used to assess the nutrition outcomes. Assessment of food security included use of validated indicators like Household Food Insecurity Access Score, Food Consumption Score and Integrated Phase Classification of food insecurity, other indicators like food consumption expenditure and food availability, or no specific methodology. Household resilience was assessed by evaluating income and poverty in relation to food production or availability. Dietary quality and diversity assessment included computing food group consumption from 24-h recalls, 7-day recalls, 7-day food frequency, or consumption of specific foods. Nutrition impact was either modelled (MOD.) completely or in part (22 studies), observed (OBS.) (19 studies), or estimated (EST.) - based on extrapolation or inference rather than formal modelling or direct observations (2 studies).

During analysis, the impact of the seed system-oriented interventions on productivity, seed access and on-farm agro-biodiversity emerged as important. Of the 43 studies, 11 did not measure or report the impact of the interventions on the seed related objective and 26 did not measure or report the impact on changes in on-farm agro-biodiversity.

3.1. Direct seed supply

Thirteen studies directly supplied farmers with seed (Table 3). Seed was largely improved with only one study providing traditional or indigenous seed (unimproved). Six studies provided seed of cereals of which four studies also included seed of other food crops, while seven studies provided mainly vegetables and tubers. The focus was promoting use of nutrient dense varieties (7 studies) or improving crop productivity (5 studies) as a means of increasing availability and consumption of nutrient dense foods and improving food availability and income which could thus increase food purchase and consumption.

Seed supply was accompanied by supply or subsidies on fertilizer, farmer capacity building, provision of technical assistance/enhancing extension services, promotion of farmer exchange of seed or promotion of crop diversification, and farmer varietal evaluation.

All 13 studies reported a positive impact on: dietary diversity/quality, food security, nutrition status and/or household resilience (Table 3). Supplied maize seed increased income resulting in increased quantities of vitamin A rich foods consumed, thus positively increasing dietary quality but with no increase in the frequency of consumption of these foods (Smale et al., 2015). However, a greater scale of adoption of improved seed could increase income and thus increase the purchase and frequency of consumption of diverse foods. While improved maize, peanut, soybean and pigeon pea seed adoption contributed to food security shown by improved household dietary diversity scores and food variety scores, adoption did not increase the food consumption scores (Ragasa and Mazunda, 2018). Also, delivering agricultural advice to households which households reported as relevant was of greater explanatory value than the type and method of delivery.

Table 3
Impact of seed system-oriented studies that directly supplied seed on nutrition.

Area of focus	Type of seed	Plant/crop	Target group and intervention	Seed and yield related outcomes[a]	Impact on nutrition outcome[a]	References
Productivity -> income -> nutrition	High yielding	Cereal, tuber, legume	Farmers in Timor-Leste Seed production, distribution, and capacity building program	Increased productivity and seed diversity (EST.)	Higher food security through increased food consumption and income (EST)	Borges et al. (2009)
		Cereal, legume	Smallholder households in Ethiopia Seed & input supply (fertilizer & pesticide), farmer seed exchange, irrigation intervention	Increased productivity & decreased seed diversity (OBS.)	Increased household and per capita income & food security (OBS.)	Emana et al. (2010)
		Cereal, tuber	Farmers in Nepal Seed distribution, capacity building & technical assistance	Increased productivity/ yield & specialization. Seed replaced traditional varieties (OBS.)	Increased food security if farmers had adequate land, never used quality seed before, & seed supply from formal channels was not well established (OBS.)	Sulaiman and Andini (2013)
		Cereal: maize	Women smallholder households in Zambia Seed distributed through the Farm Input Support Program	Positive impact on productivity/yield (MOD.). Impact on seed diversity not reported	Positive impact on dietary diversity (vitamin A rich foods) but not on frequency of consumption (MOD.)	Smale et al. (2015)
	Improved not specified	Cereal, legume	Farmers in Malawi Seed supply, input (fertilizer) subsidy & access to extension services	No effect on productivity/yield (MOD.). Impact on seed diversity not reported	Adoption of hybrid varieties increased food security but modern varieties did not (MOD.)	Ragasa and Mazunda (2018)
Nutrient dense varieties -> consumption -> nutrition	Biofortified seed	Cereal: maize Quality protein maize (QPM)	Farming households in Ethiopia Seed distribution, technical advice, fertilizer credit & extension support	Increased adoption & production of QPM. QPM replaced conventional maize varieties (OBS.)	Positive impact on nutrition status with significant decrease in wasting & stunting (OBS.)	Akalu et al. (2010)
		Tubers: sweet potato High-yielding OFSP varieties	Farming households in Mozambique Farmer varietal evaluation, training on seed production, market development for seed & products, & nutrition education	Increased productivity of OFSP (OBS.) Impact on seed diversity not reported	Increased consumption of OFSP and improved dietary quality & diversity (OBS.)	Low et al. (2007)
		Orange fleshed sweet potato (OFSP)	Farming households in Mozambique Free seed followed by purchase, capacity building, nutrition education & awareness, market & product development	Increased adoption & production (OBS.); Impact on productivity & seed diversity not reported	Increased consumption of OFSP and intake of vitamin A (OBS.)	Hotz et al. (2012a)
			Farming households in Uganda Free seed followed by purchase, capacity building, nutrition education & awareness, market & product development	Impact on productivity & seed diversity not reported	Increased consumption of OFSP and intake of vitamin A, significantly associated with lower prevalence of serum retinol <1.05 mmol/L in women & children (OBS.)	Hotz et al. (2012b)
	Both indigenous & improved seed	Nutrient dense indigenous vegetables	Vegetable farmers in Kenya Supply of seed kits, training on production & nutrition	Increased productivity (MOD.) Impact on seed diversity not reported	Positive impact on income, thus household resilience Impact differed with gender, double for men (MOD.)	Pincus et al. (2018)
	Improved seed not specified	Fruit trees, vegetables 18 nutrient dense and/or hardy plants Fruits, vegetables, legumes, tubers	Households in India (Birdi and Shah, 2015) Women in small holder households in Bangladesh (Schreinemachers et al., 2016) Seed distribution, education on seed management (Birdi and Shah, 2015), production & nutrition, promotion of diversification	Objective was to increase productivity/yield & diversity Impact on seed not reported Increased productivity (OBS.) Impact on seed diversity not reported	Increased dietary quality and diversity, & consumption of vegetables (OBS.) No change in pulse & cereal consumption (Birdi and Shah, 2015) (OBS.)	Birdi and Shah (2015) Schreinemachers et al. (2016)
Seed diversity ->diet diversity -> nutrition	Improved not specified	Vegetables, oilseeds	Poor households in Lesotho. Direct provision of seeds, cash transfer program, and agriculture & nutrition training	Positive impact on seed diversity, availability of quality seed (MOD.)	Positive impact on vegetable production & consumption, dietary diversity; food security (MOD.)	Daidone et al. (2017)

[a] Impact of studies presented a mixture of modelling (MOD.), measurement/observed (OBS.) or estimated (EST.) that is, based on extrapolation or inference; OFSP: orange fleshed sweet potato.

Seed provision coupled with training on seed and vegetable production and nutrition had a positive impact on consumption of indigenous nutrient dense vegetables and income from seed sale (Pincus et al., 2018). Impact however differed with gender, with men earning twice the income compared to women therefore influencing household resilience and security differently. Women also valued home consumption and seed security as benefits of seed production more than men. The authors recommended seed production projects to actively program gender-sensitive and gender-transformative activities (Pincus et al., 2018). A three-pronged approach that started with free supply of orange fleshed sweet potato planting material, coupled with nutrition education and awareness creation and a marketing and product development component showed an increase in vitamin A intake (Hotz et al., 2012a; 2012b).

Additional impact of direct seed supply included improved livelihoods and women empowerment (Emana et al., 2010) and greater outcomes for farmers with adequate land, those that had never used quality seed before, and where formal seed systems were not well established (Sulaiman and Andini, 2013). Despite positive impact, continued supply of free seed was a concern given the potential of undermining seed conservation and multiplication, as adoption of improved seed affected diversity when traditional varieties were replaced (Akalu et al., 2010; Sulaiman and Andini, 2013).

While an increase in productivity was reported (7 studies), one study found neutral impact (Ragasa and Mazunda, 2018), and four studies did not report on productivity. The impact on seed diversity also varied with two positive reports (Borges et al., 2009; Daidone et al., 2017), and with two potentially negative reports: a decrease in diversity (Emana et al., 2010) and the supplied seed replacing traditional variety (ies) (Akalu et al., 2010; Sulaiman and Andini, 2013). Most studies did not report an impact on seed diversity.

3.2. Improving seed access

Fourteen studies indirectly intervened in farmers' seed access through seed subsidies, vouchers, or credit (8 studies), supporting seed production or seed enterprises (2 studies), supporting the use of the extension system promoting seeds (1 study) and providing access to information and communications technology (ICT) to avail seed market information (1 study) (Table 4). Seed was largely improved (12 studies) with two studies including traditional or indigenous seed. Food crops were cereals alone (8 studies), cereals and other food crops (4 studies) and vegetables (2 studies). The focus was improving crop productivity (10 studies), supporting seed enterprises (2 studies) and enhancing seed security (2 studies) as a means of improving food availability and income from seed or agricultural produce which could increase food purchase and consumption. In some studies, improved seed access was accompanied by access to fertilizer, tools/machinery, credit, information technology, farmer training on production, support to farmers in seed enterprises, and participatory varietal selection and breeding (see Table 4).

Of the 14 studies, 11 reported a positive impact on nutrition, while two studies reported a weak positive impact, and two studies had a negative impact (Table 4). The nutrition outcomes were food security (9 studies), household resilience (7 studies) and dietary diversity and quality in (2 studies).

Over four years, impact on food security was greater following large scale distribution of seed vouchers by keeping prices in check and legumes contributing to crop diversification and dietary diversity (Levy, 2003). Mixed impact on dietary diversity with reduced starchy staples and legume diversity (groundnuts), and an insignificant impact on poverty reduction was reported (Louhichi and Paloma, 2014). This was attributed to reduced production in favor of rice, as household production contributed greatly to consumption and few households attempted to buy quantities that would match production.

Gough et al. (2003) modelled a weak-positive impact of seed and fertilizer vouchers, and a positive impact on food security. Without voucher access, most households couldn't meet their cash and consumption needs and with vouchers, household cash and production levels only marginally increased. The authors recommended that the intervention was better limited to food insecure households to better target their vulnerability (Gough et al., 2003).

Negative impacts on nutrition outcomes included an increase in calorie consumption only under intensive production of subsidized rice seed costs (Chenoune et al., 2017), and no poverty reduction which negatively affected household resilience (Fischer and Hajdu, 2015). This was attributed to poor adaptation of the hybrid seed, inability of saving/recycling provided improved seed and lack of appropriate agricultural advice.

Rajendran et al. (2016) presented a model of how participation of farmers in farmer-led seed enterprises improved their access to certified seed of indigenous vegetables, which increased income from seed sales, and positively impacted household resilience. Female-headed households however had less access to certified seed in comparison to the men. Income was estimated to be higher if farmers had more frequent contact with extension workers. For seed enterprises to succeed, strengthening of public-private partnerships for access to input, financial and extension services, capacity building at all levels of the seed value chain and an enabling policy environment are required (Guei et al., 2011; Rajendran et al., 2016).

Additional impacts included, improved farmers' seed access and income, food production and security following engagement in a participatory plant breeding program (Galie, 2013). Participation also resulted in equal access to and control of seed varieties between men and women and increased seed conservation and diversity enhancing the right to food and food sovereignty. The threat to loss of crop genetic diversity was highlighted indicating that improved high yielding varieties and increased production could marginalize production of traditional low market value crops (Meles et al., 2009). As such, participatory plant breeding and farmer-level in situ conservation of biodiversity were recommended (Meles et al., 2009).

The impact on crop productivity was positive in nine studies, neutral in two and not reported in four studies. Improving seed access also impacted seed diversity, with an increase (Galie, 2013; Levy, 2003), a decrease (Meles et al., 2009), a shift in diversity or replacement of varieties by target seed (Chenoune et al., 2017; Louhichi and Paloma, 2014; Tiwari et al., 2010), and no report (8 studies).

3.3. Effects of adoption of improved seed

Sixteen studies assessed the impact of improved seed previously released or promoted on nutrition and food security (13 studies) or evaluated aspects of agriculture that included seed and nutrition outcomes (3 studies) (Table 5). Though improved seed also featured in the first two groups, this group did not specify the intervention or seed access mechanisms, thus improved seed could be inferred as the intervention.

The focus was improving crop productivity (13 studies), nutrient dense varieties, seed diversity and seed security as a means of increasing availability and consumption of nutrient dense foods, and improving food availability and income which could increase food purchase and consumption and food security, and reduce vulnerability. Two studies included indigenous seed. Seed was of cereals (8 studies), all food crops (6 studies) and legumes (2 studies).

The majority of studies (12) reported a positive impact on nutrition, while three studies had negative impact, and one had mixed impact (Table 5). The nutrition outcomes were food security (13 studies), household resilience (8 studies), and nutrition status and dietary diversity (1 study). A positive impact on productivity was reported in seven studies, an increase in crop diversity was reported twice, and replacement of local varieties in four studies.

Untimely access to production inputs, and unfavorable rainfall conditions negatively impacted seed utilization and food security (Beyene, 2015). Evaluation of a mandatory crop specialization and land use policy targeting improved seeds and fertilizer use, found reduced food security in because households were no longer able to engage in the traditional practice of growing more than one species in the same season (Pritchard, 2013).

Hasan et al. (2018) had mixed results as adoption of improved seed significantly increased the per capita annual food expenditure but did not improve dietary diversity and food security. This was attributed to the large effects that farmer characteristics such as education, pond size, cattle ownership and market access had on food security (Hasan et al., 2018).

The mixed impact on household resilience by Cunguara and Darnhofer (2011) stressed that use of improved seed in a drought year

Table 4
Impact of seed system-oriented studies that improved farmer seed access on nutrition.

Area of focus	Type of seed	Plant/crop	Target group and intervention	Seed and yield related impacts[a]	Impact on nutrition outcome[a]	References
Productivity - > income - > nutrition	High yielding	Cereal: rice	Farmers in Sierra Leone Seed subsidies	Neutral impact on productivity/yield. Shift in diversity (production areas & cash crops) (MOD.)	Negative impact on food security (small increase in income & consumption only in intensive production) (MOD.)	Chenoune et al. (2017)
	high yielding, early maturing	Cereal: Tef, sorghum	Farmers in Ethiopia Improved seed distributed through extension, NGOs and then saved by farmers	Positive impact on productivity/yield & decreased seed diversity. Quantity & diversity of seed was relatively low (MOD.)	Positive impact on income & thus household resilience (MOD.)	Meles et al. (2009)
	High yielding, resistant to biotic and/or abiotic stress	Cereal: maize	Smallholder farmers in South Africa Input subsidies, free choice of varieties & products at fairs	No effect on productivity/ yield (OBS.) Varieties not locally adapted. Impact on seed diversity not reported	Adoption did not reduce poverty thus no impact on household resilience (OBS.)	Fischer and Hajdu (2015)
	Early maturing, resistant to biotic and/or abiotic stress	Cereal: rice	Smallholder farmers in Sierra Leone Subsidized high-quality seed	Increase in productivity/ yield & specialization (MOD.) Seed replaced other varieties	Positive impact on income, food security & household resilience But mixed impact on dietary diversity (less starchy staples & legume diversity, small increase in fruit) (MOD.)	Louhichi and Paloma (2014)
	Improved not specified	Cereal: maize	Maize farmers in Nepal Improved maize varieties from participatory varietal selection and/or community-based seed production	Increased in productivity/ yield Seed replaced traditional varieties (OBS.)	Increased food security & food availability (OBS.)	Tiwari et al. (2010)
			Farmers in Malawi Input (improved seed & fertilizer) Subsidy Program (vouchers)	Increase in productivity/ yield. (MOD.) Impact on seed diversity not reported	Increase in food security (MOD.)	Dorward et al. (2008)
		Cereal, legume	Smallholder farmers in Malawi Distribution of starter pack and starter pack vouchers (improved seed & fertilizer)	Increase in productivity/ yield (MOD.). Impact on seed diversity not reported	Weak positive impact on food security (MOD.). Without starter packs, inability of most households to meet cash & consumption requirements	Gough et al. (2003)
			Smallholder farmers in Malawi	Increased productivity/ yield & crop diversification (OBS.)	Adoption increased food security after large scale distribution. Legumes contributed to dietary diversity (OBS.)	Levy (2003)
		Cereal, legume, oil seed	Smallholder farmers in Uganda Access to ICT-based market information	Increased use of improved seed (MOD.). Impact on seed diversity not reported	Positive impact on food security income & household resilience (MOD.)	Kiiza and Pederson (2012)
		Vegetables	Women farmers in Bangladesh Training and credit for improved seed	Objective was to increase productivity. Impact on seed not reported	Positive impact on income & weak impact on women empowerment & child nutrition status (MOD.)	Hallman et al. (2003)
Seed enterprise - > productivity - > income - > nutrition	Traditional or indigenous	Indigenous vegetables	Indigenous vegetable farmers in Tanzania Model farmers in farmer-led seed enterprises to improve access to certified seed	Objective was to increase productivity. Increased access to quality seed. Impact on seed diversity not reported	Positive impact on income and HH resilience among seed producers (MOD.)	Rajendran et al. (2016)
	Early maturing & traditional or indigenous	Cereals: rice, maize, sorghum, millet	Smallholder farmers in Cameroon Creation of smallholder seed enterprises with supply of seed; training in seed production; creation of partnerships for extension services, input access & seed certification	Intervention increased production of quality seed (OBS.). Impact on seed diversity not reported	Increased income & grain for consumption thus positive contribution to food security & HH resilience among seed producers (OBS.)	Guei et al. (2011)
Seed security - > diet diversity - > nutrition	Resistant to biotic and/or abiotic stress	Cereal, legume, vegetable	Farmers in Syria Participatory plant breeding program that included seed selection & management, Training in agriculture	Positive impact on productivity/yield, conservation & diversity; increased farmer access to seed (OBS.)	Estimated increase in food security. Associated food security with 2 food-related rights: right to food and food sovereignty. Estimated increased access to and control of seed varieties (EST.)	Galie (2013)
	Both indigenous & improved seed	Cereal: maize[b]	Households in Swaziland affected by drought Input trade fair vouchers for farmers to purchase individually selected inputs at fairs (seeds, equipment)	Increased productivity/ yield (OBS.). Impact on seed diversity not reported	Increased net maize grain availability led to improved household food availability (food security) (OBS.)	Mashinini et al. (2011)

[a] Impact of studies presented a mixture of modelling (MOD.), measurement/observed (OBS.) or estimated (EST.) that is, based on extrapolation or inference.
[b] Fairs included maize, sorghum, groundnuts, jugo beans, beans, cow peas, mung beans and sesame but study only assessed purchase of maize.

Table 5
Impact of seed system-oriented studies on the effects of adoption of improved seed on nutrition.

Area of focus	Type of seed	Plant/crop	Target group and intervention	Seed and yield related impacts[a]	Impact on nutrition outcome[a]	References
Productivity - > income - > nutrition	High yielding	General	Households in Ethiopia	Positive increase in productivity/ yield (MOD.) (Bogale, 2012). Impact on productivity (Habtewold, 2018) seed diversity not reported (Bogale, 2012; Habtewold, 2018)	Increased consumption expenditure (MOD.(Bogale, 2012) '1 and OBS.(Habtewold, 2018)) thus improved food security & household resilience	Bogale (2012) Habtewold (2018)
		Cereal: maize	Maize farmers in Tanzania	Positive increase in productivity/ yield from adoption of improved seed and fertilizer (MOD.). Impact on seed diversity not reported	Positive impact of improved seeds & fertilizer use, on welfare & food availability. For food access, utilization & stability, heterogeneity noted between improved seeds & fertilizer & between food security pillars (MOD.)	Magrini and Vigani (2016)
		Cereal: rice	Producers & consumers in Bangladesh	Adoption of rice intensification & improved varieties increased productivity/yield & specialization (MOD.). Seed replaced traditional varieties	Positive impact of intensification on food security, overall economic welfare and thus on household resilience (MOD.)	Shew et al. (2019)
	Early maturing and resistant to biotic and/or abiotic stress	General	Coastal smallholder farmers in Bangladesh	Adoption of climate smart agriculture (CSA) practices through saline tolerant, flood tolerant drought resistant, early variety and seed storage. Impact on seed diversity not reported	Increased per capita annual food expenditure but not for household food insecurity access scale & dietary diversity (OBS.)	Hasan et al. (2018)
	High yielding, resistant to biotic and/or abiotic stress	Cereal: maize	Smallholder farmers in Zambia	Adoption of seed increased productivity (MOD.). Seed replaced traditional varieties	Positive impact on income, consumption expenditure, food security, poverty and thus household resilience (MOD.)	Khonje et al. (2015)
			Maize farmers in Kenya	Objective was to increase productivity. Impact on seed not reported	Positive impact on income & thus household resilience. Chemical fertilizer use did not contribute to household income gains (MOD.)	Wainaina et al. (2018)
	Resistant to biotic and/or abiotic stress	Legume: pigeon pea, chickpea	Households in Ethiopia and Tanzania	Positive increase in productivity/ yield (MOD.). Increased crop diversification	Positive increase in consumption expenditure and thus household resilience (MOD.)	Asfaw et al. (2012)
		General	Pastoral and agro-pastoral households in Ethiopia	Not reported	Negative impacts on food security due to late delivery of production inputs, and unfavorable rainfall conditions (OBS.)	Beyene (2015)
		Cereal: maize	Farming households in Nigeria	Positive increase in productivity/ yield (MOD.). Impact on seed diversity not reported	Positive impact on per capita food expenditure, poverty, seasonal food scarcity, thus improved food security & household resilience (MOD.)	Wossen et al. (2017)
	Both indigenous & improved	Legume: bean	Bean farmers in Rwanda Research & dissemination	Adoption of climbing bean increased yield Climbing bean variety replaced non-climbing variety (MOD.)	Increased on per capita household consumption, reduced poverty, & thus improved food security & household resilience (MOD.)	Katungi et al. (2018)
		Cereal: maize	Households in Mozambique Assessment of relationship between use of improved technologies & household income during a year of drought	Objective was to increase productivity. Impact on seed not reported	Household income from production & off-farm earnings increased household resilience. Estimated positive impact on income for households with better market access. Estimated negative impact on income for others (MOD.)	Cunguara and Darnhofer (2011)
	Improved not specified	General	Rural subsistence farmers in Rwanda Mandatory crop specialization and land use policy	Mandatory crop specialization & land use policy improved seeds & fertilizer use. Impact on seed not reported	Reduced food security (OBS.)	Pritchard (2013)
Nutrient density - > consumption - > nutrition	Biofortified – breeding	Cereal: maize	Poor, rural farmer households in Ethiopia QPM to improve child protein intake	Objective was to increase specialization. Seed replaced traditional maize varieties	Modelled positive impact of QPM on protein intake in non-breastfed children thus diet quality (MOD.)	Gunaratna et al. (2019)
Seed diversity - > diet diversity - > nutrition	Resistant to biotic and/or abiotic stress	Cereal, tuber, legumes, vegetables	Farming households in South Africa Adoption of crop diversification as response to climate change	Positive impact on seed diversity & availability (OBS.)	Positive impact on food security with mitigated negative effects of actual & potential climate change (OBS.)	Shisanya and Mafongoya (2016)
		General				

(continued on next page)

Table 5 (*continued*)

Area of focus	Type of seed	Plant/crop	Target group and intervention	Seed and yield related impacts[a]	Impact on nutrition outcome[a]	References
Biotechnology (genetically modified) - > productivity, income - > consumption - > nutrition	Improved not specified		Farmers, in food insecure countries (Shao et al., 2018)	Increase in productivity/yield (MOD.). Impact on seed diversity not reported	Negative impact on food security (MOD.)	Shao et al. (2018)

[a] Impact of studies presented a mixture of modelling (MOD.), measurement/observed (OBS.) or estimated (EST.) that is, based on extrapolation or inference.

significantly increased income for households with better market access but negatively impacted households with poor market access and use of full-time hired workers. This was attributed to the combined effect of entry barriers to improved technologies and structural impediments to markets.

Magrini and Vigani (2016) explicitly analyzed food security effects of adoption of improved maize seed and inorganic fertilizers showing that effects on the four pillars of food security are too complex to replace direct food security indicators with general welfare indexes. Adoption of improved seeds and chemical fertilizer were complementary. Adoption of the two technologies had a positive impact on food availability while for food access, utilization and stability, impact of improved seeds and chemical fertilizers alone varied and sometimes had opposite effects plausibly related to either technology working better depending on household contexts. Improved seeds were modelled to guarantee more diversified micronutrient intake and enhance food utilization. Seed sovereignty reduced when farmers adopted only improved hybrid maize seed but was unchanged when adopting only fertilizers. Suggesting that intervention packages composed of more than one technology, could more efficiently cover all the pillars of food security (Magrini and Vigani, 2016). This was also supported by models by Wainaina et al. (2018). Additional observations included the need for wider technology promotion and dissemination; vulnerability assessments to guide and monitor interventions; addressing production constraints; strengthening the informal seed sector; and improving extension, credit and input services (Asfaw et al., 2012; Beyene, 2015; Bogale, 2012; Khonje et al., 2015).

4. Discussion

The review mapped impact of seed system interventions on nutrition and food security, and seed diversity, use and security in low- and middle-income countries. Nutrition impact varied, with more reports of positive compared to mixed/negative impact.

The distribution of study characteristics could reflect the direction of mainstream seed system interventions. There were more studies on starchy staples, with a focus on improving crop productivity, use of improved seed and emphasis on increasing direct and indirect seed access. There was less evidence on traditional or indigenous seeds and sustainable integration of seeds into farmers' seed systems. Most studies (63%) focused on cereals, with other food crops like legumes, roots and tubers, vegetables, and fruits together representing less than 25% of studies where they were the sole focus. Despite the increasing global and research shift towards improving access to diverse diets (Burlingame and Dernini, 2012; Fanzo et al., 2013; FAO et al., 2021), seed interventions appear skewed towards improving the productivity and income from staple foods. Given that cereals (wheat, rice, and maize) represent large shares of diets and national food supplies, and similarities in global food demand and supply are increasing, over representation of cereals and improved seed in both research for development and diets is resulting in a reduction in agrobiodiversity (Bioversity International, 2017; Khoury et al., 2014).

From the review process, it was evident that most of the studies failed to provide any information either on the seed system interventions at all, or how the seed system intervention impacted nutrition outcomes. This was also noted in a recent vegetable food systems review (Harris et al., 2022). Nonetheless, both positive and negative impact on nutrition and food security were noted and could be attributed to lack of the enabling factors identified as: (i) use of gender sensitive approaches to ensure gender equal access to and control of seed; (ii) approaches that consider the situation and status of farmers, including agro-ecological and farming systems context, and vulnerability; (iii) use of participatory approaches that involve farmers in seed selection, evaluation, breeding, production and conservation; (iv) capacity building on seed(s), technologies, crop production, seed production, seed enterprises, conservation and nutrition; (v) use of multi-component interventions comprised of supporting and/or complementary interventions as opposed to a single component intervention; (vi) ensuring seed characteristics are suited to the farming environment, are of high quality and acceptable to farmers, and coupled with timely access; (vii) considering and strengthening the selected seed system(s) and market context(s) such as functionality of the formal or informal seed systems, farmer access to quality seed and level of farmer participation; and (viii) use of appropriate nutrition outcomes, making evaluation and impact assessment more explicit.

Crop or variety specialization at the expense of local crop diversity or among the resource poor or farmers in marginal areas, had a negative impact on nutrition and food security. This could be due to household's inability to adequately fill the food gap that was previously produced with market purchased food (Kissoly et al., 2018; van Wijk et al., 2018); increased production costs that accompany improved seed and reduced seed sovereignty (Wach, 2016); and increased vulnerability as agrobiodiversity protects against climate stress, pests and diseases that could devastate a uniform crop (Wolff, 2004).

The impact and enabling factors correspond with previous reviews reporting seed system intervention impacts on nutrition. That while a positive impact was noted, the extent varied with season and country (Arouna et al., 2017) and only if market and credit access are sufficient (Dias, 2010). Reports also indicated that promotion and adoption of biofortified seed was cost-effective in improving diet quality especially for rural areas with underdeveloped markets or limited market access (Bouis, 2003; Bouis and Welch, 2010). Moreover, interventions on biofortified seed should ensure they do not undermine seed multiplication/seed value chains and seed diversity conservation (Low et al., 2007), and do affirm dietary diversity (Bouis and Welch, 2010; Johns and Eyzaguirre, 2007). Most studies (63%) reported impact on food security either with or without impact on household resilience. Studies with food security and household resilience outcomes were more likely to focus on improving crop productivity as a pathway from seeds to food availability, income, and food security (Nabuuma et al., 2020). While studies with dietary quality and diversity and nutritional status as outcomes were more likely focused on nutrient dense varieties as a pathway from seeds to improved availability and diet quality. Highlighting the importance of a system approach to analyze, intervene and evaluate the production system and food environment (HLPE, 2017).

A wide range of nutrition terminologies, and indicators, mainly unvalidated, were used. Evaluation studies should make use of validated food and nutrition security indicators to facilitate comparability and quantification of impact (INDDEX project, 2018). Food and nutrition security is complex and where possible, evaluations should take into account the different dimensions (Haysom and Tawodzera, 2018; Lele et al., 2016).

Nutrition impact was largely modelled where model quality verification was not always clear. While they provide good insight, direct verification provides more substantial evidence. Observation of impact requires evaluation after an appropriate length of time which is often limited by short project timeframes (Bird et al., 2019). Also, seed system interventions likely lack sufficient food environment and nutrition expertise to enable thorough nutrition impact assessment.

Whilst the study aim was nutrition impact, intermediate outcomes between seed and nutrition were identified where positive and negative impacts on seed diversity were noted. For the latter, specialization, replacement or mixing of local varieties with target seed(s) had potentially negative impacts on productivity and food and nutrition security over time and could lead to loss of local agrobiodiversity, especially among poorer households/communities. More evidence on the impact on seed diversity and strategies to sustainably ensure agrobiodiversity conservation are needed (Bioversity International, 2017; Wolff, 2004).

Overall, results emphasized the importance of system, context specific and/or diversity sensitive approaches. Impact on nutrition was more positive among less vulnerable farmers, those with higher socioeconomic status or resource access, and for men compared to women, underscoring importance of vulnerability assessments and gender sensitive approaches (Asfaw et al., 2012; Beyene, 2015; Bogale, 2012; Cunguara and Darnhofer, 2011; Fischer and Hajdu, 2015; Gough et al., 2003; Khonje et al., 2015). Where systems were less functional or farmers had limited access or participation, direct/indirect seed supply had a higher positive impact, and so did strengthening farmer seed production and conservation. The majority of studies had multi-component interventions that improved seed access through seed provision; built capacity; provided technical support; increased input access (fertilizer, organic manure, equipment); enhanced credit and information access, and/or developed markets. Where specific combinations of interventions were context specific.

The authors were surprised at how many studies were excluded simply because they did not outline the specificities related to seed in their intervention. Many studies clearly relied on seed, however, most often this was not mentioned in any way. At most, it was simply stated that seed was distributed, without any mention of the type of seed or how it was distributed. This highlighted the inadequate attention to seed systems in nutrition-sensitive agriculture projects. In addition, sustainable integration of target seeds into farmers' seed systems beyond direct/indirect seed supply and the long-term impacts of interventions or technologies on the seed system emerged as key missing aspects. This includes development of relevant seed systems to accompany the introduced (often improved) seed and assessing/addressing impact on seed sovereignty and agrobiodiversity to ensure sustainable seed access and utilization. Interventions did not analyze the consequences for seed systems, especially in the longer term. Nutrition sensitive programming therefore needs to consider seeds to be truly nutrition sensitive. The seed system provides leverage points through which an enabling environment for achieving a positive nutrition outcome can be enhanced (FAO, 2017). In fact, for contexts with poorly developed formal seed systems (most rural communities in low and middle-income countries), interventions that reduce seed sovereignty and agrobiodiversity while increasing dependence on the formal system may be detrimental and unsustainable (Galie, 2013; Gough et al., 2003; Magrini and Vigani, 2016; Meles et al., 2009). For example, for traditional vegetables in Eastern Africa, while the formal seed system had higher potential for quality seed, the informal system had higher potential for seed access (Ayenan et al., 2021).

While interventions on staple crops that increase reliance on the formal system may be sustainable when productivity increase supports continued seed purchasing, this may not be the case for non-income or non-staple crops (secondary crops). Secondary crops, especially in rural smallholder households, are mainly grown by women for household consumption and are crucial for maintaining agrobiodiversity and household access to diverse diets (Luna-González and Sørensen, 2018; Pincus et al., 2018; Pudasaini et al., 2013).

Efforts to ensure farmers have the legal right to save, develop, exchange and sell seeds can have little consequence if the knowledge, skills, networks, and varieties in the informal seed sector are undermined. Challenges of farmer agency must be mitigated so that farmers define their own seed systems which enhance their livelihoods, food security and nutrition. For given contexts and crop(s), both formal and informal systems need to be assessed to address shortcomings and increase the participation of and benefits to farmers. Farmer seed production for example through quality declared seed or contract farming can contribute to seed availability and accessibility (Croft et al., 2018; Kansiime et al., 2021).

Therefore, in limited resource settings, strengthening the informal system and seed sovereignty may be essential, and interventions aimed at nutritional security should also analyze and test approaches to ascertain longer term seed access. In fact, Lammerts van Bueren et al. (2018), argue for systems-based breeding where ecological and cultural contexts and trade-offs are considered, as well as development and integration of a multitude of suitable breeding strategies, tools, and policies to provide the best conditions for a broad genetic base that enhances seed and food security and food sovereignty (Lammerts van Bueren et al., 2018).

5. Conclusion

Seed system-oriented interventions have the potential to influence nutrition outcomes as both positive and negative impacts on food security, household resilience, dietary quality and diversity and nutrition status were noted. There were similar impacts on seed access, use, diversity, and productivity. Studies emphasized the importance of system, context specific and/or diversity sensitive approaches and use of multi-component interventions. However, most studies did not explicitly focus on nutrition outcomes or rigorously assess nutrition impact; impact was largely modelled; and interventions/evaluations geared more towards the seed than the seed system. While most interventions evaluated adoption and impact of seed, few reported or analyzed strategies for sustainable inclusion into the seed systems context(s) or impacts on seed sovereignty and agrobiodiversity. Given that most evidence targeted improved cereal seed, additional research on the nutritional impact of seed system interventions in fruits and vegetables and traditional/indigenous seed across different food crops is needed. As well as more evidence from observational studies, using validated nutrition indicators and impact on longer term seed access from both the formal and informal seed systems.

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