

# Advances and trends in ecological organic agriculture (EOA) technologies and research on fruit vegetables produced in Tanzania

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## Abstract

Ecological organic agriculture (EOA) is a holistic production management system that can solve many problems in the vegetable crops' value chain (VC). It is, however, unclear about the EOA technologies for the fruit vegetable VC that have already been validated or are in process of validation in Tanzania. A systematic literature search on EOA technologies relevant in Tanzania was conducted for research articles from 2010 until 2021. Most 10(30.4%) studies on fruit vegetables were equally distributed each 5(15.2%) in the years 2019 and 2020, respectively. A total of 33 records on fruit vegetables covered eight (8) regions of mainland Tanzania and one (1) region from the island of Zanzibar. Most 18(55%) studies were conducted in the Morogoro region. Based on the fruit vegetable VC, 26(68.4%) studies were for field establishment and management. Nine (9) key areas were identified, where most 9(27.3%) studies were on crop productivity and protection. Seventeen (17) EOA technologies were applied in fruit vegetables, mostly biocontrol 7(21%) in tomatoes. Overall, 27(81.8%) studies only researched the EOA technologies, while 3(9.1%) studies validated the EOA technologies, 2(6.1%) researches were in progress, and 1(3.0%) was progressing validation. Few 3(9.1%) studies portrayed the involvement of youth and women using the principles of participatory action research (PAR) during the validation. Generally, the EOA technologies are readily available, require minimal skills and labour, are cost-effective, sustainable, easily implementable in the fruit vegetable VC and can be simply accessed and utilized in cultivating organic fruit vegetables.

**Keywords:** fruit vegetables, ecological organic agriculture, EOA technologies, validation, Tanzania

**Review Methodology:** A systematic literature search was conducted for published and/or in press research articles from 2010 until 2021 on EOA for relevant publications: Google Scholar, Web of Science Core Collection, PubMed, Science Direct, Semantic Scholar and Scientific Electronic Library Online (SciELO). A literature search was performed using a combination of the following terms: ecological, organic, agriculture, technologies, vegetables, fruit vegetables, biocontrol, grafting, mulching, soil fertility, fertilizers, protected farming, water management, irrigation, pruning, seed, nursery establishment, nursery management, harvesting, postharvest, Tanzania. In addition, the references from the articles obtained by this method were used to check for additional relevant materials. The desk review was

supplemented by face-to-face interviews (physical survey) and phone conversations to get further information, documentation and validity on researched EOA technologies. Researchers from different recognized institutions, that is, Sustainable Agriculture Tanzania (SAT), Tanzania Agricultural Research Institute (TARI-Tengeru), Tanzania Plant Health and Pesticide Authority (TPHPA) and Sokoine University of Agriculture (SUA) were contacted and checked for any available research/upcoming studies not yet published on EOA technologies for vegetables VC. Data collected using checklists administered to the respondents from the selected institutions included study title, name and contact details for the researcher, year when the study was conducted or published, study setting, type of vegetable(s), EOA technology, and how women, youth and marginalized groups have been considered during validation of EOA technologies. All statistical analyses were performed using MS Excel version 19 software to obtain frequency and percentages for the selected variables.

### Introduction

The agriculture sector accounts for a comparatively small share of the global economy but remains an unexceptional contributor to the global economy, and central to the lives of a greater proportion of the global population [1]. About 1.3 billion (19%) people out of the world's 7.1 billion population in 2012 were directly engaged in farming, but agriculture (including the relatively small hunting, fishing, and forestry sectors) represented just 2.8% of overall income [1]. Nevertheless, in developing countries (low- and middle-income) including Tanzania etc., where most of the world's farmers are located, agriculture accounts for a much greater share of national income and employment in their rural populations [2]. It was revealed that in Tanzania, the agricultural sector stands as the second largest contributor to the national economy after the services sector, which accounts for 44.30% of the national economy [3]. In Tanzania, the agriculture sector accounts for 25.88% of the national economy, whereby 18.93% is contributed by the crops subsector followed by livestock (4.70%) and fishery subsectors (2.25%), respectively. This sector alone employs 65.5% of Tanzanians, and in favorable seasons, it covers more than 100% of the domestic food needs, consequently playing a bigger role in the reduction and alleviation of poverty for most Tanzanians [4].

Despite the significant benefits of agriculture, there are various limitations associated with human engagement in exploiting the potential of this sector. As a result of human population growth and pressure for production intensification, an increase in the utilization of agricultural inputs, and particularly reliance on inorganic fertilizers, pesticides, and irrigation systems have been widely acknowledged [5, 6]. Such practices have resulted in negative impacts on soils, biodiversity and the environment at large, thereby affecting crop and animal genetic diversity and welfare, human nutrition and increased costs for public health, and communities' vulnerability to external shocks.

Overall, enhancement and maintenance of system productivity and resource quality are essential for a sustainable agricultural system of various horticultural crops including vegetables. Therefore, the ecological organic agriculture initiative (EOA-I) is executed to promote ecologically sound strategies and practices

among diverse stakeholders in production, processing, marketing and policymaking to safeguard the environment, improve livelihoods, alleviate poverty and guarantee food security [7]. The EOA project is implemented by eight countries in Africa: four in Eastern Africa (Ethiopia, Kenya, Uganda and Tanzania) and four in West Africa (Mali, Nigeria, Benin and Senegal) are rolling out the initiative, with an overall goal of mainstreaming ecological agriculture into national agricultural production systems, plans and policies. Sustainable Agriculture Tanzania (SAT) is leading pillar I (research and applied knowledge) in collaboration with other partners implementing EOA-I's core funded by Swiss Agency for Development and Cooperation (SDC). In Tanzania, the initiative is led by Tanzania Organic Agriculture Movement (TOAM) from among nine African countries.

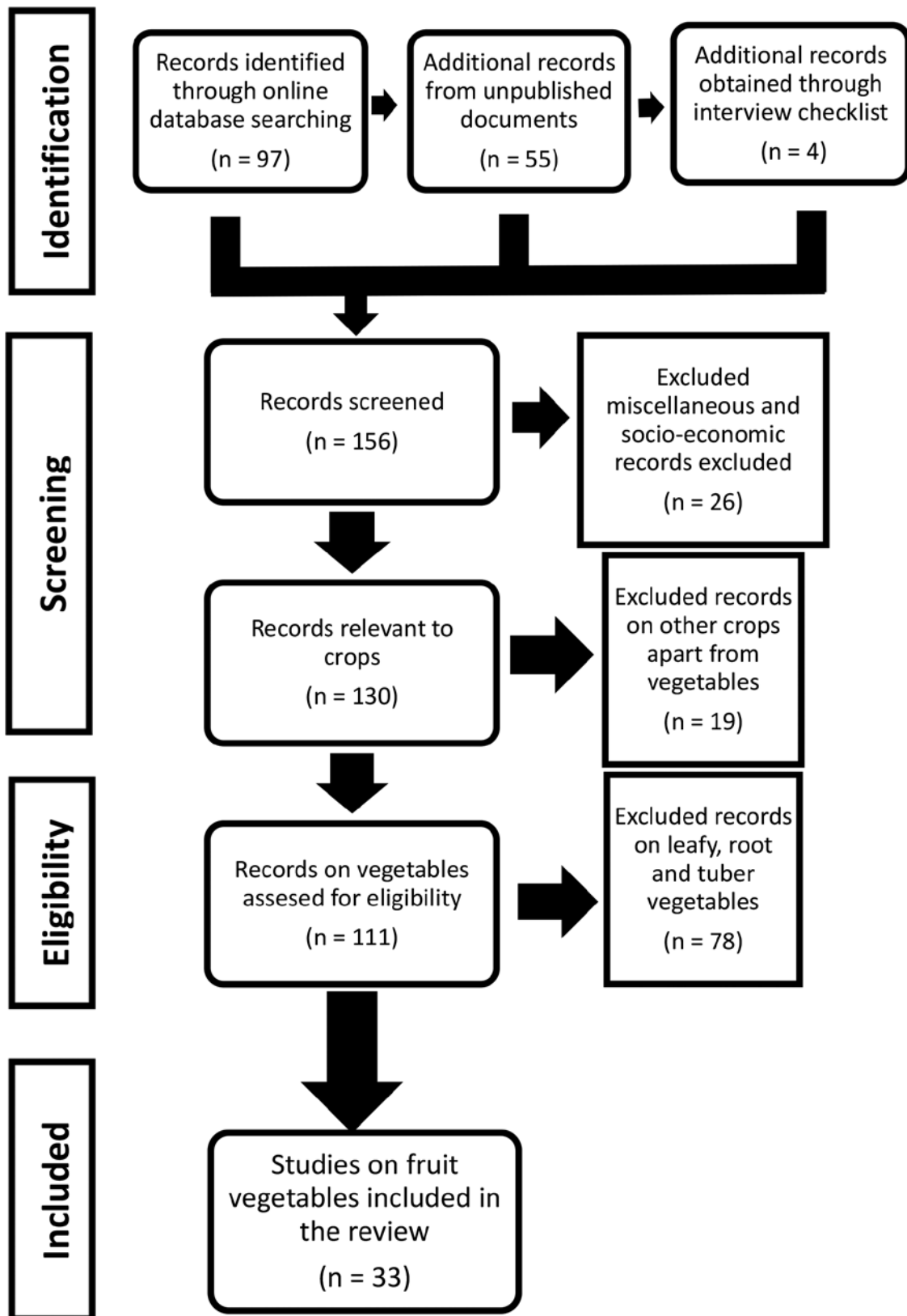
Ecological organic agriculture (EOA) is a holistic production management system that considers the agro-ecosystem in all its diversity. EOA technologies can solve many problems in the vegetable crops value chain (VC), as this system can maintain soil productivity, and effectively control pests by enhancing natural processes and cycles in harmony with the environment [8]. Studies on organic fruits and vegetables [8] have been highlighted EOA strategies in other areas globally, especially on the limited availability of quality seed and plant materials; balanced nutrient composition of organic amendments and a timely nutrient release with plant nutrient uptake; limited effective tools for pest, disease and weed management; new biological control agents and biopesticides in response to the alarming resistance to synthetic pesticides; strategies that promote or impair microbiological food safety; tools for organic farming to prevent microbial pre- and postharvest proliferation. It is, however, unclear about the EOA technologies that have already been validated or are in process of validation by various entities in Tanzania. This study, therefore, provides comprehensive information on the available researched EOA technologies regarding fruit vegetables VC in Tanzania.

### Selection of available research studies on EOA technologies and exclusion reasons

A total of 97 records were identified through online database searching, and additional records were retrieved

from unpublished documents (55) and interview checklist (4) (**Fig. 1**). Titles and abstracts of 156 records were screened for the year (2010–2021), fruit vegetable crops,

EOA technologies, and country (Tanzania), and finally, 33 records of studies that met the inclusion/eligibility criteria were included in the review.



**Figure 1.** Flow diagram for selection of the studies and reasons for exclusion.

### Trend of research on EOA technologies in Tanzania

The number of relevant EOA research studies on fruit vegetables in Tanzania ranged from 1 to 5 per year over the period 2010–2021 with an upward trend. Most 10 (30.4%) studies were equally distributed each 5 (15.2%) in the years 2019 and 2020, respectively, while few studies 1 (3.0%) were in the years 2011, 2013 and 2017, respectively.

### Distribution of research among study areas in Tanzania

Thirty-three records available on EOA technologies along with the fruit vegetable VC covered eight regions of mainland Tanzania and one (1) region from the island of Zanzibar (**Table 1**). Eighteen (55.0%) studies conducted in the Morogoro region reported on biocontrol, mulching, organic fertilizers, grafting, harvesting timing, soil fertility improvement and storage facilities [22–39]. Seven (21.0%) studies conducted in Arusha region reported biocontrol [9–12], nursery establishment, mulching, water management [13], protected farming [14] and grafting [15]. Two (6.0%) studies conducted in the Kilimanjaro region reported water management and mulching [18, 19]. One (3.0%) study conducted in the Iringa region reported on organic fertilizer application [16]. One (3.0%) study conducted in Mbeya reported on cropping sequence and organic fertilizers [21].

One (3.0%) study conducted in Japan but for Tanzania case reported on spacing and pruning practices [17].

Based on stages in the fruit vegetable VC, 26 (68.4%) of the researched EOA technologies were for field establishment and management, followed by 9 (23.7%) studies on seed and nursery stage particularly on nursery establishment [13], biocontrol [22, 23, 25, 40] and grafting [15, 27–29], while three (7.9%) studies were on harvest and postharvest stages [30, 38, 39] (**Table 2**).

### Key area(s)/subject matter for EOA technologies in fruit vegetables

Nine key area(s)/subject matter for EOA technologies applied along with the fruit vegetable VC in Tanzania have been identified (**Fig. 2**). Most (9, 27.3%) studies evaluated EOA technologies that fall under crop productivity and protection, followed by 8 (24.2%) studies on crop protection, and 5 (15.2%) on soil fertility and crop productivity area/subject matter.

### EOA technologies applied in fruit vegetables

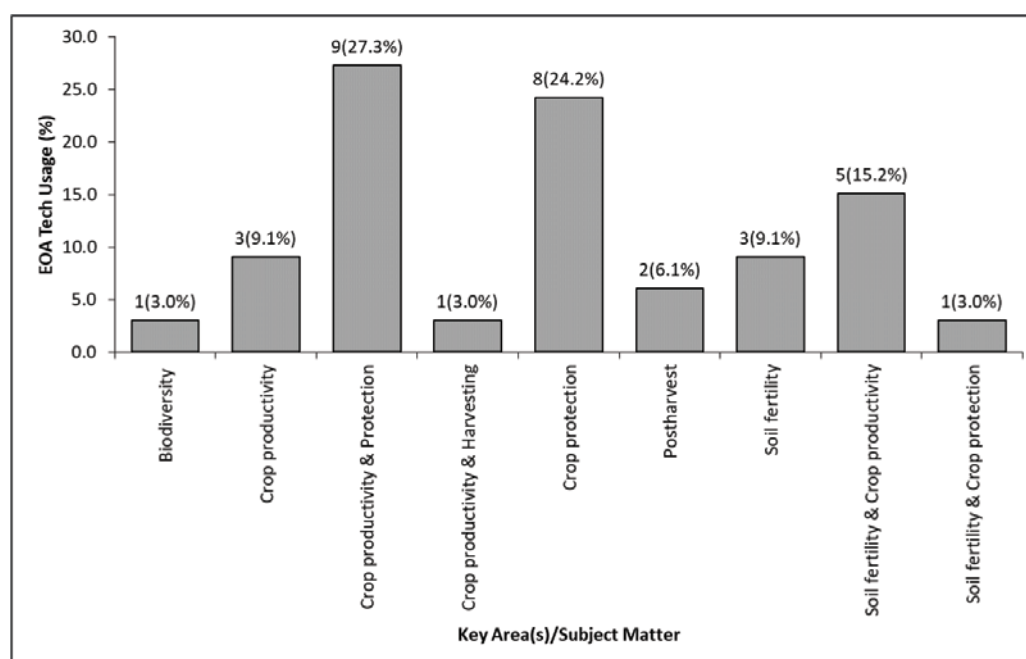
Seventeen EOA technologies identified in the fruit vegetable VC are shown in **Fig. 3**. Of all the 33 studies on fruit vegetables included in the review, 7 (21%) studies evaluated the biocontrol technologies in tomatoes [9–11, 22–24], followed by 4 (12%) studies on organic

**Table 1.** Distribution of research among study areas in Tanzania.

Study location	Frequency (percentage)	EOA technology	fruit vegetables	Source
Arusha	7 (21.0%)	Biocontrol	Tomato	[9–12]
		Nursery establishment, Mulching & Water management	Eggplant	[13]
		Protected farming	Cucumber	[14]
		Grafting	Eggplant, African eggplant & tomato	[15]
Iringa	1 (3.0%)	Organic fertilizers	Tomato	[16]
Japan for Tanzania case	1 (3.0%)	Spacing & Pruning	Sweet pepper	[17]
Kilimanjaro	2 (6.0%)	Water Management & Mulching	Cucumber & tomato	[18, 19]
Manyara	1 (3.0%)	Protected farming & Biocontrol	Tomato & sweet pepper	[20]
Mbeya	1 (3.0%)	Cropping sequence & Organic fertilizers	Tomato	[21]
Morogoro	18 (55.0%)	Biocontrol	Tomato	[22–24]
		Biocontrol & Mulching	Tomato	[25]
		Biocontrol & Organic fertilizer	Cucumber & squash	[26]
		Grafting	Tomato & eggplant	[27–29]
		Harvesting timing	Eggplant	[30]
		Mulching	Okra & tomato	[31, 32]
		Organic fertilizers	Sweet pepper & tomato	[33–36]
		Soil fertility analysis	Tomato	[37]
		Storage facility	Eggplant	[38]
				Tomato
Morogoro & Unguja	1 (3.0%)	Mulching, Biocontrol & Organic fertilizers	Okra, sweet pepper & tomato	[40]
Tanga	1 (3.0%)	Mulching & Organic fertilizers	Tomato & sweet pepper	[41]

**Table 2.** Distribution of EOA technologies in fruit vegetable value chain.

Stage of value chain	Frequency (percentage)	EOA technology	fruit vegetables	Source
Seed and Nursery	9 (23.7%)	Nursery establishment	Eggplant	[13]
		Biocontrol	Tomato, okra & sweet pepper	[22, 23, 25, 40]
		Grafting	Tomato, eggplant & African eggplant	[15, 27–29]
Field establishment and Management	26 (68.4%)	Soil fertility analysis	Tomato	[37]
		Biocontrol	Tomato	[9–12, 22–24]
		Water Management & Mulching	Eggplant	[13]
		Protected farming	Cucumber	[14]
		Organic fertilizers	Sweet pepper & tomato	[16, 33–36]
		Spacing & Pruning	Sweet pepper	[17]
		Water Management & Mulching	Cucumber & tomato	[18, 19]
		Protected farming & Biocontrol	Tomato & sweet pepper	[20]
		Cropping sequence & Organic fertilizers	Tomato	[21]
		Mulching	Okra & tomato	[25, 31, 32]
		Biocontrol & Organic fertilizer	Cucumber & squash	[26]
Harvest and postharvest	3 (7.9%)	Mulching & Organic fertilizers	Okra, sweet pepper & tomato	[40, 41]
		Storage facility	Eggplant	[38]
		Harvesting timing	Tomato	[39]
			Eggplant	[30]

**Figure 2.** Key area(s)/subject matter for EOA technologies applied in fruit vegetables.

fertilizers in both sweet pepper and tomato [33–36], and 4 (12%) studies on grafting in tomatoes using rootstocks from eggplant, and African eggplant [15, 27–29].

### Status of EOA technologies applied in fruit vegetables

Generally, 27 (81.8%) studies only researched the EOA technologies, while 3 (9.1%) studies validated the EOA

technologies, 2 (6.1%) research was in progress and 1 (3.0%) was progressing validation. Out of the 17 EOA technologies identified in the review (**Fig. 4**), six (6) technologies were prominent. Most 7 (21.2%) studies researched the biocontrol technologies [9–12, 22–24], followed by studies that researched the usage of organic fertilizers of about 4 (12.1%) [16, 33, 34, 36], grafting technology of about 4 (12.1%) [15, 27–29], mulching [25, 31, 32], water management and mulching technologies of about 2 (6.1%) [18, 19], and improved storage facility of about 2 (6.1%)

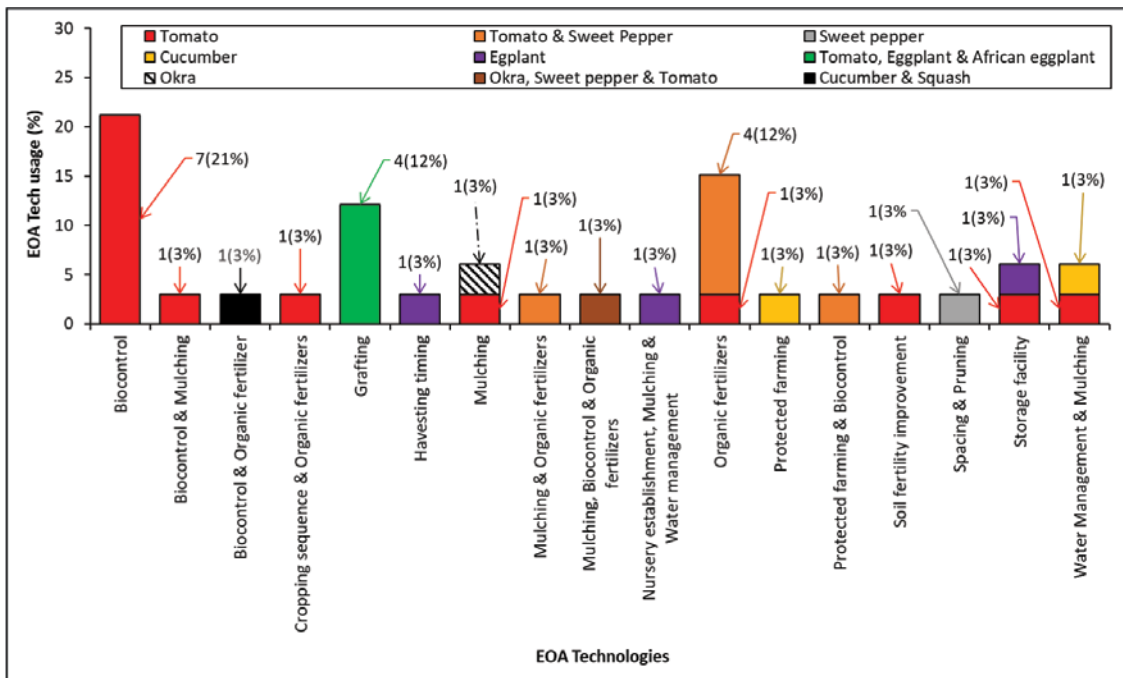


Figure 3. EOA technologies applied in fruit vegetables.

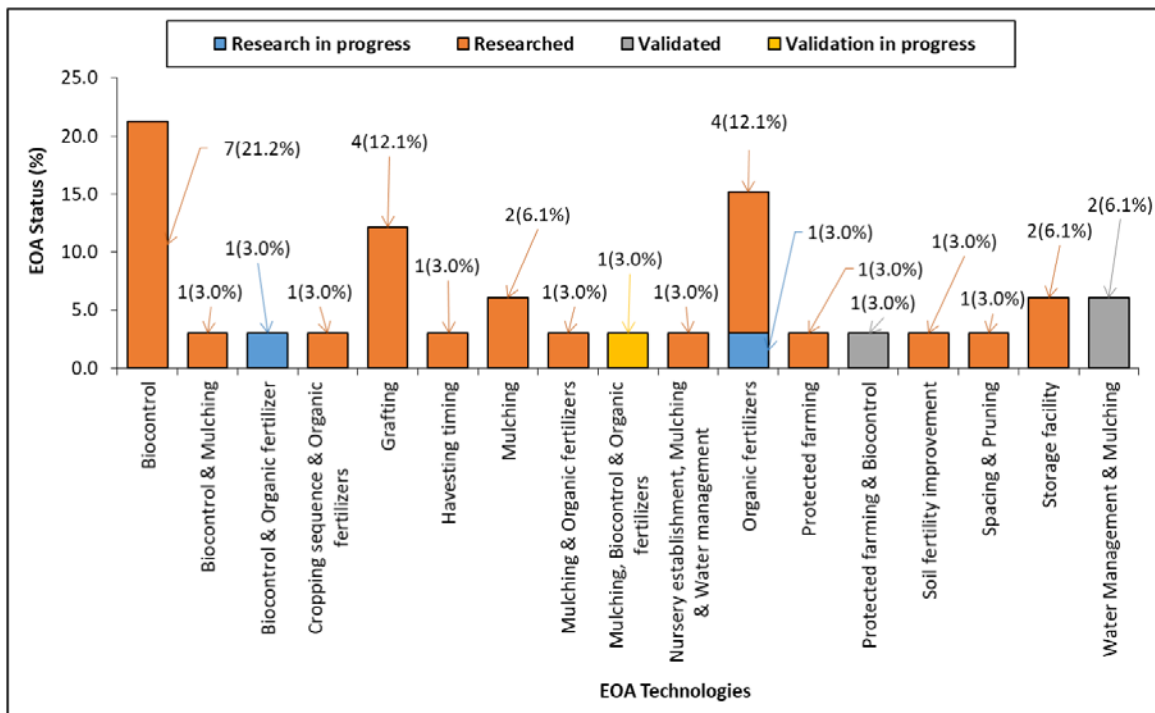


Figure 4. Status of EOA technologies applied in fruit vegetables.

[38, 39]. This is mainly triggered by the predominant challenges facing farmers, that is, insect pests and diseases, soil and plant nutrient deficiency, and high postharvest losses.

The application of crude botanicals (plant extracts) and hot water treatments as biocontrol techniques have the potential to reduce pests and disease pressure on

tomatoes [11, 23–25, 40]. Mulching using dry grasses, twigs, corn-maize residues and rice husks retains soil moisture content, enhances plant growth and fruit yield, and reduces pest incidence and fruit rot [13, 18, 19, 25, 31, 32, 40, 41]. Merits of using organic fertilizers such as compost amended with Minjingu phosphate rock fertilizer and poultry manure closely

resemble those of mulching, except that organic fertilizer increases soil nutrient composition and release rate [16, 18, 21, 26, 33–36, 40, 41]. Water management techniques (pitcher irrigation, drip tape irrigation and moisture reduction using cattle manure and mulching) significantly improve water usage efficiency and can therefore be widely applied in the semi-arid (water-scarce) areas of Tanzania, and hence are helpful in reducing the pressure from freshwater resources. Furthermore, irrigation techniques can be used as cost-effective solutions in fertigation [13, 18, 19]. Perforated polyethylene bags, CB-CR (at 13°C and 16°C) and ZECC storage conditions have been shown to increase fruit freshness (low shriveling), shelf-life, delay fruit color change, maintain fruit internal qualities, reduce fruit physiological weight loss and economically viable for storage of tomato fruits, particularly mature green fruits [38, 39].

Most research done in Tanzania has impacted EOA technologies, which are significant to EOA farmers. Therefore, Erasto [40] conducted field experiments at different sites in Tanzania (i.e., Menge-Vianzi, Mayanga-Kimambila and Mikese villages in the Morogoro region and Bungi-Unguja in Zanzibar island) to validate the recommended EOA technologies from various studies [23, 25, 31–33, 35]. The validation involved extraction of research findings from these studies, then applying them directly to the farmers' fields and actively engaging the farmers in the selection of the most effective and feasible EOA technology. Furthermore, the synthesized findings and recommendations drawn by researchers on the 17 EOA technologies identified in the fruit vegetable VC are illustrated in **Table 3** for easier uptake of VC actors.

### Involvement of women, youth and marginalized groups during validation processes

Few 3 (9.1%) studies have portrayed the extent of youth and women's involvement during the process of validating EOA technologies [11, 19, 40]. These studies used the principles of participatory action research (PAR), whereby challenges in the communities were identified by researchers through consultations with farmers, and then research-tested and/or provided solutions to those problems. These studies purposively selected farmer group members with women, youth [11, 19, 40] and elders [19], but did not limit other farmers/non-group members who were actively involved in the production of horticultural crops including fruit vegetables. The results of this validation research showed that extracts of neem and *Lantana camara* enhanced the control of *T. absoluta*, whiteflies, aphids, mites and wilt disease of tomato [11]; mulching using a combination of dried leaves, twigs, grass, and corn residue and irrigating once or twice a week increased tomato yield [19]; seed treatment with botanicals before seed sowing improved seed germination and seedling vigor, and reduced disease incidence and severity; organic

mulches reduced weed density and fruit rots, and enhanced crop growth, and minjingu fertilizer and poultry manure improved crop growth [40]. Since women and youths in the study locations were involved in the on-farm demonstration of the results, the majority of these farmers learnt and appreciated the EOA technologies applied through the holistic approaches; hence, it can also be linked with promoting the development, dissemination and application of sustainable EOA practices, for enhanced health of plants, animals, humans and the environment as a whole. Furthermore, this would encourage farmers engaged in fruit vegetable production to reduce and/or eliminate extensive usage of toxic synthetic pesticides, improve water usage efficiency and reduce the pressure from freshwater resources.

### Conclusion and recommendations

Generally, the desk review revealed that EOA technologies are readily available, require minimal skills and labour, and are cost-effective, sustainable, and easily implementable in fruit vegetable VC. They can therefore be simply accessed and utilized by organic farmers involved in cultivating and storing fruit vegetables. Most researched technologies particularly on seed treatment, nursery type, field establishment and management were mainly conducted in the laboratory, screenhouse or researcher-based field trials without the active involvement of farmers, therefore requiring validation. Some EOA technologies including protected farming structures and plant propagation require fine tuning. Protected farming structures, such as open tunnels with a plastic film roof, increased plant growth but did not improve yields because of a lack of protection from insect pests. Plant propagation technique particularly grafting advanced flowering and fruit harvest but caused partial incompatibility after transplanting. Therefore, vigorous eggplant and African eggplant rootstocks with the capability of carrying scions of tomato cultivars are required to improve graft compatibility and plant growth and reduce the incidence of plant wilting and death after transplanting in the field. Also, the utility of grafted tomato plants for open-field production in Tanzania needs to be confirmed, and an investigation on how grafting affects the hydraulic conductivity of xylem vessels in the later developmental stages of grafted plants is required.

### Acknowledgments

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**Table 3.** Synthesized findings and recommendations for easier uptake of value chain actors.

EOA technologies	Vegetable	Key findings	Recommendations drawn by authors	Source	Status
1. Biocontrol	Tomato	1. Seed treatment with oils of eucalyptus, rosemary and niaouli at 2% concentration inhibited the growth of <i>Xanthomonas perforans</i> and reduced the incidence and severity of bacterial leaf spot (BLS)	1. Eucalyptus and rosemary oils can be used to control BLS in tomatoes. 2. Investigation is required on the shelf-life of these oils, their mode of action and their effects on seed-borne pathogens of cropping systems. 3. Investigation is required on the shelf-life of seed treatment with crude extracts, mode of action, analysis of effective oil fractions in controlling BLS and the effects of these oils on tomato yield. 4. Investigation is required on the interaction of the essential oils with hormones and phenolic acids responsible for regulating physiological processes during seed germination. 5. Further work is required to investigate the effectiveness of eucalyptus and rosemary oils in the control of other seed-borne pathogens of tomato and in other crop systems	[22]	Researched
		1. <i>Aloe vera</i> , <i>Coffee arabica</i> and <i>Yucca schidigera</i> extracts increased the number of normal seeds and had no effect on seedling vigor, height and weight	1. Plant extracts can be used as a seed treatment in tomatoes. 2. Further research is required to test the effectiveness of plants extracts against BLS under farmers' conditions. 3. Research is needed to identify plant extract bioactive fractions and their mode of action	[23]	Researched
		1. Leaf dipping in <i>Commiphora swynnertonii</i> resin effectively enhanced <i>Tuta absoluta</i> adults' mortality (100%), fruit yield and reduced yield loss	1. The plant extract is recommended in integrated pest management strategies for the control of <i>T. absoluta</i>	[24]	Researched
		1. <i>Aspergillus oryzae</i> ( $1.0 \times 10^8$ conidia/mL) caused <i>T. absoluta</i> larval mortality (up to 70%), inhibited pupation (by 84.5%) and reduced adult emergence (by 74.4%) and life span (up to 5 days)	1. Isolates of <i>Aspergillus</i> species can potentially be used as active ingredients in formulating biocontrols to control pests in farmers' fields. 2. Field evaluation and formulation of biopesticide from <i>A. oryzae</i> isolates that could control <i>T. absoluta</i> to reduce the use of synthetic chemicals for protection are needed	[9]	Researched
		1. Locally available entomopathogenic fungi and plant extracts from <i>Bersama abyssinica</i> stem bark, <i>Commiphora africana</i> leaves, <i>Tergetes minuta</i> seeds and <i>Moringa oleifera</i> essential oil from seeds, controlled <i>T. absoluta</i> . 2. These biocontrols caused 60%–80% mortality of adults and larvae of <i>T. absoluta</i> in the laboratory and open-field conditions	1. Plant extracts and essential oils are recommended for further analysis and for consideration as remedies against <i>T. absoluta</i> in tomato	[10]	Researched

Continued

Table 3. Continued.

EOA technologies	Vegetable	Key findings	Recommendations drawn by authors	Source	Status
		1. Neem and <i>Lantana camara</i> enhanced the control of <i>T. absoluta</i> , whiteflies, aphids, mites and wilt disease of tomato in farmers' fields	1. Biocontrol methods can be used to control pests and diseases. 2. There is a need to research other plants and animal materials to develop bio-pesticides	[11]	Researched
		1. Significant repellence of tomato whiteflies ( <i>Bemisia tabaci</i> ) was attained using bio-extracts from endophytes ( <i>Fusarium</i> sp. and <i>Alternaria</i> sp) of lemongrass leaves (54%), pyrethrum flowers (76%) and leaves (36%). 2. Significant lethality and leaf miners ( <i>Tuta absoluta</i> ) larvae and whiteflies	1. Bio-extracts of lemongrass and pyrethrum flower were recommended due to higher levels of flavonoids and total phenolic contents as active ingredients than in pyrethrum leaves	[12]	Researched
2. Biocontrol & Mulching	Tomato	1. Hot water significantly reduced bacterial populations on tomato seeds, fewer sun-scald fruits, increased the number of fruits and yield (number of fruits/plants, average fruit weight and higher marketable yields per acre)	1. Seed treatment and mulch can reduce disease infestation and improve tomato yield	[25]	Researched
3. Biocontrol & Organic fertilizer	Cucumber & Squash	1. Enhance biodiversity of beneficial insects/pollinators, reduce the reliance on pesticides to control fruit flies and enhance the productivity of cucurbits through farmyard manure supplements	1. None	[26]	Research in Progress
4. Cropping sequence & Organic fertilizers	Tomato	1. Minjingu Phosphate Rock alone or combined with compost or crotalaria increased tomato yield. 2. Cabbage inclusion in tomato cropping sequence increased soil available phosphorus (207.9%) than when it was omitted (85.39%)	1. The use of Phosphate Rock and including cabbage in crop rotations can be used to restore phosphorus on deficient soils	[21]	Researched
5. Grafting	Tomato, Eggplant & African eggplant	1. Grafting eggplant rootstocks (EG190, EG195 and EG203) with hybrid tomato cultivars significantly led to partial incompatibility based on a higher incidence of adventitious roots at the graft union, plant wilting and death after transplanting in the field. 2. Grafting these eggplant rootstocks significantly reduced plant height, and stem diameter of tomato cv. Assila and Monica in comparison with ungrafted controls. 3. Grafting eggplant rootstocks with tomato hybrid cultivars significantly advanced flowering and fruit harvest compared to ungrafted controls	1. Further studies are required to determine vigorous rootstocks capable of carrying scions of hybrid tomato cultivars for improved graft compatibility and plant growth	[27]	Researched

Continued

Table 3. Continued.

EOA technologies	Vegetable	Key findings	Recommendations drawn by authors	Source	Status
		<p>1. Grafting success was obtained indoors in a healing room, and higher survival of grafted seedlings occurred when grafted plants were placed in a healing chamber within the healing room. Grafted seedling survival was higher with eggplant (EG195) than with tomato Hawaii (7996) rootstock when the seedlings were grafted 3 weeks old at 20°C–27°C temperature and 86%–100% relative humidity. 2. In field trials, non-grafted tomato plants were taller than grafted plants, but no difference in dry plant biomass. Non-grafted plants flowered 2 days earlier than grafted plants but the difference was not exhibited in the second field trial. 3. Broad-leaf, grass and sedge weed biomass did not differ significantly in response to grafting. However, sedge density and grass weeds were higher with the grafted tomato compared to non-grafted. 4. Total and marketable yields were higher from the grafted tomato plants than the non-grafted plants in a trial conducted during the rainy season. In contrast, the response was reversed during the dry season. 5. With respect to fruit quality attributes, fruits from grafted tomatoes were firmer than those of non-grafted</p>	<p>1. Grafting is possible under low-resource conditions in Tanzania. 2. Further research is warranted to confirm the utility of grafted tomato plants for open-field production in Tanzania</p>	[28]	Researched
		<p>1. Graft success between eggplant rootstocks and local tomato cultivars was higher (86%–100%). However, grafting tomato rootstock (Hawaii 7996) with local tomato cultivars significantly resulted in a lower graft success (30%–50%) during the hardening stage in the open nursery. 2. This high graft success is achieved when 21°C–32°C temperature and 85%–95% relative humidity in the dark and transparent chambers are maintained, and coupled with misting of the grafted seedlings when wilting signs appear</p>	<p>1. Eggplant rootstocks (EG190, EG195, EG203 and EG219) can be grafted with Tanzanian local tomato cultivars with up to 100% graft success. 2. In order to increase tomato yield, farmers should graft their varieties with these soil-borne-diseases-resistant eggplant rootstocks. 3. Further research is needed to optimize the healing conditions for grafted local tomato cultivars on tomato rootstock (Hawaii 7996)</p>	40	Researched

Continued

Table 3. Continued.

EOA technologies	Vegetable	Key findings	Recommendations drawn by authors	Source	Status
		1. The grafting success rate was more than 90% at 15°C and 20°C, but significantly decreased (20%) with higher temperatures (40°C). 2. Lower grafting success rate and vigor; that is, plant height, biomass and the number of leaves were recorded for heterografted than homografted plants. 3. The negative impacts of grafting on plant vigor were related to a reduction in the hydraulic conductivity measured in grafted plants, especially heterografted plant stems close to the grafting point	1. Degree-days can be of advantage to predict the ready-to-graft stage of seedlings, as it reduced the discrepancy among trials. 2. Further research is needed to investigate how grafting affects the hydraulic conductivity of xylem vessels in the later developmental stages of grafted plants	[15]	Researched
6. Harvesting timing	Eggplant	1. Shiny cream white-harvesting stage (83 days after planting-DAP) significantly increased yield of Tengeru white variety, and 25% yellow color stage (95 DAP) increased yield of Manyire green variety as well as carbohydrate and fiber contents	1. Harvesting immature fruits for high vitamin and mineral contents and delayed harvesting for the highest yield are recommended. 2. Further studies are required to determine the effect of harvesting stages on the yield and nutritional quality of African eggplant	[30]	Researched
7. Mulching	Tomato	1. Dry grass ( <i>Panicum</i> spp.) mulch improved the number of fruits, and marketable fruit yield and reduced the incidence of American bollworm and blossom end rot	1. Mulching improves yield and reduces pest infestation	[32]	Researched
	Okra	1. Rice husk mulch significantly enhanced the number of pods (8) and yield (98,440 kg/ha) for the Pusa sawani cultivar	1. Rice husk as mulching material improved okra production and significantly controlled weed	[31]	Researched
8. Mulching & Organic fertilizers	Tomato & sweet pepper	1. Mexican weeping pine and wild lemongrass mulches increased the yield and quality of sweet pepper and tomato. 2. Both mulches effectively suppress the number and dry weight of weeds in both crops. 3. Increased number of beneficial arthropods. 4. Both types of mulch lasted throughout the production period without the need for replenishment. 5. Compost increased OC, TN, Na, Fe and Mn between 3 and 12 months of composting and released nutrients as early as 3 months after heaping	1. Mulching improves the yield and quality of tomato and sweet pepper. 2. Further research is required to understand the benefits of compost from plants used for mulching. 3. Understanding the relationship between beneficial arthropods and insect pests where mulch is used	[31]	Researched
9. Mulching, Biocontrol & Organic fertilizers	Tomato & sweet pepper	1. Seed treatment with botanicals before seed sowing reduced disease incidence and severity, and improved seed germination and seedling vigor. 2. Organic mulches reduced weed density, fruit rots and enhanced crop growth. 3. Minjingu fertilizer and poultry manure improved crop growth	1. None	[40]	Validation in Progress

Continued

Table 3. Continued.

EOA technologies	Vegetable	Key findings	Recommendations drawn by authors	Source	Status
10. Nursery establishment, Mulching & Water management	Eggplant	1. Tray transplanting increased seed use efficiency and yields more than with bare roots. 2. Drip tape fertigation substantially increased yields (30%–100%), saving on water use and labour costs more than furrow irrigation. 3. Mulch retained moisture in the soil, and reduced weed growth and labour requirement for weeding	1. Training farmers to adopt nursery establishment, mulching and water management systems. 2. To provide farmers with capital in order to purchase the materials needed to adopt the described techniques	[13]	Researched
11. Organic fertilizers	Tomato	1. Amendment of compost with Minjingu Phosphate Rock (MPR) increased soil organic carbon more than crotalaria green manure	1. Compost amendment with MPR increases soil organic carbon more than crotalaria green manure. 2. Further research on whether mixing crotalaria with a slower decomposing material can increase organic matter build-up	[16]	Researched
		1. Coffee pulp composted with MPR increased phosphorus uptake of tomato plants 18 times than control plants	1. Composting coffee pulp with Minjingu phosphate rock can potentially improve phosphorus availability and uptake by tomato	[34]	Researched
		1. Higher number of leaves, shoot length, the number of fruits and weight of fruits were attained by adding poultry manure (8 t/ha)	1. Poultry manure (8 t/ha) is sufficient for improving tomato production	[35]	Researched
	Sweet pepper	1. Improve organic fertilizers to ensure an increase in nutrient composition, and release rate and attain maximum efficiency of organic fertilizers application methods to enhance soil fertility	1. None	[36]	Research in progress
		1. Minjingu mazao fertilizer (10:20:15) significantly increased sweet pepper fruit yield (15.6 t/ha) compared to non-application (9.4 t/ha)	1. Minjingu mazao is recommended because it significantly increases fruit yield and it is easily available	[32]	Researched
12. Protected farming structures	Cucumber	1. Nethouses significantly reduced fruit flies' populations than in open plots and rain shelters. 2. Nethouses with small mesh increased marketable yields (70.9 and 96.9 t/ha), followed by large mesh (67.4 and 53.1 t/ha), open tunnels (12.9 and 9.1 t/ha) and open plots (3.8 and 7.2 t/ha)	1. Use of nets, especially small mesh size, significantly protected crops against major insect pests of cucumber, as well as a conducive environment for crop development under local climatic conditions	[14]	Researched
13. Protected farming structures & Biocontrol	Tomato & sweet pepper	1. High marketable fruits (97.9%) and yield due to the synergistic effect of <i>Metarhizium anisopliae</i> (38.6 t/ha; 17.6 ± 2.2) and net houses (37.5 t/ha) on <i>T. absoluta</i> in tomato. 2. High marketable fruits (94.6%) and the yield on sweet pepper due to whitefly control in the net house (17.6 t/ha) and open field (16.2 t/ha)	1. Integrating biopesticides and net houses effectively managed <i>T. absoluta</i> on tomato and whitefly on tomato and pepper and increased marketable yields	[20]	Validated
14. Soil fertility analysis	Tomato	1. Farms at Uponda village are deficient in Ca, Mg, Na, K, S, C, OC, P, and total N leading to poor crop growth and productivity	1. Application of poultry manure together with better agronomic practices are encouraged to improve soil fertility and increase productivity	[37]	Researched

Continued

**Table 3.** Continued.

EOA technologies	Vegetable	Key findings	Recommendations drawn by authors	Source	Status
15. Spacing & Pruning	Sweet pepper	1. Plants with four stems reduced thrips incidence. 2. Narrower spacing (40 cm between rows) increased yield despite thrips occurrence	1. Narrow spacing with none-pruned practice can be adaptable if early harvest for a short period is targeted. 2. However, to sustain harvest, the plants with four stems should be adopted due to better yield with minimal thrips occurrence	[17]	Researched
16. Storage facility	Eggplant	1. Fruits stored in perforated polyethene bags significantly maintained fruit water content and shelf-life though they suffered from incidence of decays depending on eggplant variety	1. Further studies are required to evaluate the effect of fruit disinfection prior to storage in perforated polyethene bags on the shelf-life of eggplant fruits	[38]	Researched
	Tomato	1. Higher percentage of marketable fruits on Mature Green fruits stored in CoolBot Cold Rooms (CB-CR) at 13°C (98.9%) and 16°C (97.8%) than Zero Energy Cooling Chamber (ZECC) (71%) and Ambient (57%). 2. CB-CR at 13°C and 16°C was economically viable with a benefit–cost ratio (B:C) of 1.7 and 2.2, respectively. 3. The B:C ratio of storing mature green tomato fruits in ZECC (0.61) was poor during the season but relatively better than ambient (0.44)	1. The adoption of CB-CR technology is recommended to ensure better and more economical storability of tomatoes during peak harvesting seasons when demand is low	[39]	Researched
17. Water Management & Mulching	Cucumber	1. Pitcher irrigation, fresh or compost cattle manure and dry grass mulch increased the total yield of cucumber and improved water use efficiency	1. Water conservation techniques together with mulching significantly improve water usage efficiency and increase cucumbers yield	[18]	Validated
	Tomato	1. Mulching using a combination of dried leaves, twigs, grass, and corn residue and irrigating once or twice a week increased tomato yield	1. Mulching and watering (1 or 2 times/week) can significantly increase tomato yield	[19]	Validated

completion of the expected outputs. We are also thankful for the inputs by the Network of Organic Agriculture Research in Africa (NOARA) Tanzania Chapter platform members who participated in the intensive Research stakeholders' workshop in Dodoma Tanzania. This workshop with its intention to connect all NOARA Tanzania Chapter platform members and discuss on how to improve research in the organic agriculture subsector also provided constructive critiques to improve this desk review.

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