Annual Report 2019

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September 2020
Melkassa

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Preface

This Annual Report highlights the major research findings, achievements and services provided at Melkassa Agricultural Research Center (MARC) of the Ethiopian Institute of Agricultural Research (EIAR) in 2019. The report includes the output in Crops, Livestock, Natural Resource Management, Agricultural Engineering, Agricultural Economics, Agricultural Extension and Communication, Plant Biotechnology, Plant Protection, and Technology Multiplication research. The report provides a concise summary of research findings that can be used by researchers and concerned development practitioners. This report is a vital document essential in the research tradition that has to be up held in the modern research communication system so that information will be accessible in both soft and hard copies.

I am indebted to the research and support staff of MARC for their contributions to produce this report by making ground works and facilitations at every point. I am highly obligated to the organizing and editorial team who took the hand work in cleaning and shaping the bulk of information and presenting it concisely in this handy document.

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Agricultural Economics Research

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The following are the major outputs of the Agricultural Economics Research Process.

The result of survey indicates that the size of cultivated land owned is about 1.42ha. The mean cultivated land owned sizes about 1.85 ha in Oromia, 1.36ha in SNNP, 1.21ha in Amhara and 0.80ha in Tigray regions. Plowing is the dominant operation that is carried out using draft animal power and hence almost 95.2% of the farmers under study do own traditional plows locally known as *Maresha*. The second most owned machine by the farmers is a knapsack sprayer. Animal drawn carts are the third most owned machines as the farm transport is a critical issue for the farmers. As a recent technology, ownership of hermetic bags is observed to be a well-promoted improved storage option. About 11% of the farmers found in adopting the Broad Bed Maker (BBM) technology. When it comes to the individual farmers' ownership of large mechanization technologies, quite negligible proportion of the farmers purchased machines such as tractors, combine harvesters, threshers, feed choppers, and milk processing technologies.

The application of diverse mechanical power sources is almost inexistent; some areas may use tractors or combine harvesters, others may practice some level of mechanical threshing, water pumps, or maize shellers. Even also utilizations may differ among crops grown within the same location, for instance, in areas where wheat is mechanized, it is not comparable with that of barley. Among the large-scale mechanization, it is found out that nearly 15% of the farmers apply tractor power for land preparation followed by combine harvesting which accounts for 14.4%. Comparatively, Oromia region has the largest utilization with a share of 28.8%,

Tigray 15.8%, SNNP 12.7% and Amhara 4.5%. Combine harvesting is also mostly practiced in Oromia National Regional State (28.5%), SNNP (19.3%), Amhara (10%) and Tigray (unavailable). Threshing and maize shelling practices are also better in Oromia. Despite low proportions, tractor attached broadcast, row planters, and chemical spray are exceptionally utilized in the same region. In contrast to other cereals, wheat is the better-mechanized crop in terms of the application of tractors and combine harvesters.

Unavailability of the service mechanization service a major bottle neck. The high price of hiring remains to be the second most important constraint that hinders utilizations despite the needs of machines. Others described that the service providers do not appear on time and ownership of small land sizes does not favor adoptions of large machines. Thus, the service given by the service providers needs to be offered by a range of appropriate technologies according to the diverse farm sizes. The steep nature of farms will not encourage service providers. Despite not equally, the issues of lack of access to credit to pay for the service fees, lack of access to roads for easy entry of machines, fragmented farmlands, machine, and soil-related problems are important issues that need to be further investigated.

Plot level data was collected from 31 farmers that were selected from 3 districts. Labor cost was the major input accounting for 58% in common bean production. Oxen draft power was the second most important input accounting for about 20% followed by fertilizer (13%) and seed (10%) respectively. Farmers obtained 14017 and 1807 (ETB) per hectare on average from common bean yield revenue and common bean straw sales respectively. The average variable cost of common bean was ETB 9459/ha, with an average Gross return (GR) of ETB 15825/ha. The benefit cost ratio (BRC) of 1.67. This indicates that beans production in the study area is profitable and may serve as a means of poverty reduction and holds good prospect for alternative income generation for smallholder farmers in the CRV of Ethiopia. The results were also submitted to be published in journal and first comment corrected and sent for further dissemination.

Agricultural Extension and Communication Research

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Agricultural Extension and Communication (AEC) department accomplished a number research and development activities and produced remarkable results. The major results for the year 2019 presented as follow.

Under this activity, demonstration of improved onion and common bean with their production practices were demonstrated in Adama, Dugda, Adamitulu-Jidokombolcha(AJ), Shalla and Lume districts on 149 farmers' fields (25 women and 124 men). The technologies used forpromotion were: Onion (Nafis, Nasik Red and Bombay Red as a check) and Common bean: (Sab-632, Sab-732 and Nasir as check). Relevant data were collected and analyzed. The mean yield obtained from onion demonstration shows Nafis variety have a better yield performance than the other two demonstrated varieties in all districts except in AJ district.

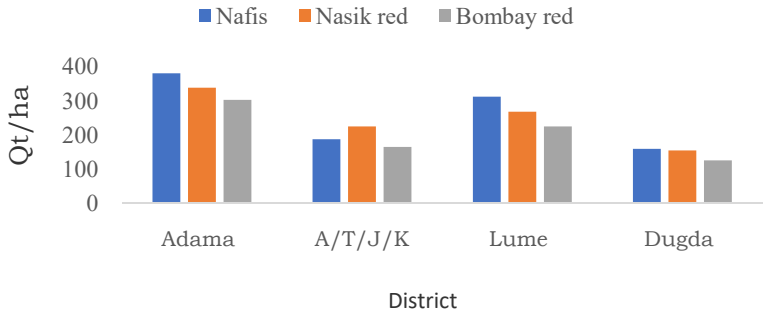

Figure 1: Yield performance of onion varieties in the demonstration districts

: Two common bean varieties (Sab-632 and sab-732) were demonstrated by using Nasir as a standard

check. The demonstrations were conducted at four districts (Adamitulu-Jidokombolcha, Dugda, Shalla and Adama). Fourteen hosting farmers (12 male and 2 female) participated in the demonstration. Module-based Training has been also given to farmers, experts, and DAs about the improved common bean production practices. At the maturity stages of the crop field day have been conducted and extension materials were distributed. Finally, relevant data were collected and analyzed.

Table 1: Summary of yield result of common bean varieties demonstrated, 2019

Parameters	SAB-632	Nasir	SAB- 732
Min (qt/ha)	15	9.4	8.4
Max (qt/ha)	29.7	28.6	27.5
Mean (qt/ha)	22.35	19	17.95

Note: Qt=quintal (100kg)

Based on the previous year's demonstration result farmers selected common bean varieties were popularized at farmers' field in a cluster approach for wider demand creation. The popularization was conducted at three districts (Adamitulu-Jido-kombolcha, Shalla and Adama). Site and farmers selection were done in collaboration with district experts and development agents. 25.55 ha of land was covered by the popularization activity (10 ha in Shalla, 6.55 ha in AJ and 9 ha in Adama districts).

In the common popularization activity, 45 farmers (39 men, 6 women) were participated. Training was also given for hosting farmers, experts, and DAs. In Adama district, 9 ha was planted by Awash-2 variety, AJ district 6.55 ha was covered by Nasir, at Shalla SER-119 and SER-125 were planted on5 ha of land respectively.

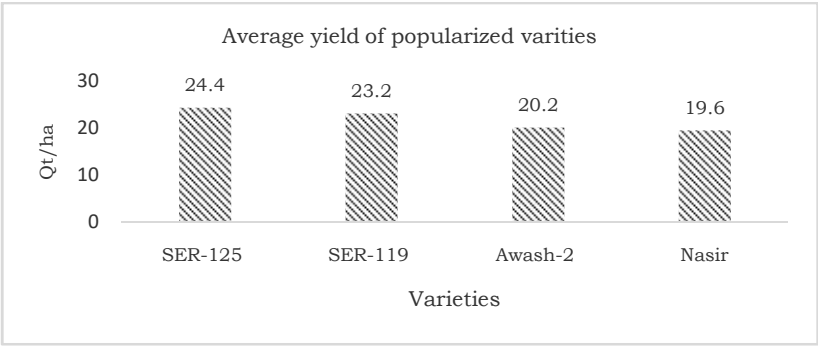

Figure 2: Yield performance of common bean varieties

As part of demonstration, trainings were organized for farmers, development agents (DAs) and experts. Totally 576 peoples were trained on production and management of improved technologies of maize (238), onion (82) and fruit (256).

Table 2. Compositionof trainee by technology expertise and gender

Trainee	Common bean			Onion		
	Male	Women	Total	Male	Women	Total
Farmers	80	18	98	33	1	34
DA	14	7	20	24	5	29
Experts	13	5	18	4	2	6
Total	107	30	136	61	8	69

Field days and media (print and audiovisual) were parts of technology demonstration and promotion. In the year 2019, in Lume, AJ, Shalla and Adama districts a series of field day were organized on common bean and onion production involving 633 participants including government officials and farmers at large took part on the field day observed and gave their feedback about the technologies demonstrated (Table 3).

Table 3. Field day participants in the demonstration (onion and common bean) field

Participant	Male	Women	Total
Farmers	458	100	558
DAs, Experts, Gov Officials	63	12	75
Total	521	112	633

During the field days and center visit by various stakeholders, printed leaflet was produced in Amharic and Afan Oromo and disseminated to 3000 users.

Bedru Beshir, Tadesse Berhanu, Legesse Hidoto, Feyera Merga, Goshime Muluneh, Yalfal Temesgen and Moti Jaleta. (2019). Enhancing resilience and sustainability on African farms: Key findings and recommendations for Ethiopia. SIMLESA Project country synthesis report. CIMMYT/EIAR. El Batan/Addis Ababa, Ethiopia.

Bedru Beshir, Edenshaw Habte and Tadesse Birhanu. (2019). From trial plots to mega fields: How Conservation Agriculture-based Sustainable Intensification can become the new normal in Ethiopia? Enhancing Agricultural Resilience and Sustainability in Ethiopia. Policy brief.

Tadesse Birhanu, Bedru Beshir and Edenshaw Habte. (2019). Maintaining crop residues in the field saves soils and improves crop yields. Enhancing Agricultural Resilience and Sustainability in Ethiopia. Policy brief.

Tadesse Birhanu, Bedru Beshir and Edenshaw Habte 2019. Conservation Agriculture-based Sustainable Intensification: Minimal tillage saves resources, improves yields on Ethiopian farms. Enhancing Agricultural Resilience and Sustainability in Ethiopia. Policy brief.

Bedru Beshir, Berhanu Amsalu, Mulugeta Tamir, Dagimawit Tsegaye, Bezawit Yilma and Selamawit Ketema. (2018). Cowpea production, Marketing and utilization in Ethiopia. Research Report 121. Ethiopian Institute of Agricultural Research. Addis Ababa, Ethiopia.

Elias Zerfu and Bedru BeshirAbdi2018. Expanding the Frontier: Extension Research or Research on Extension. *In*: Abebe Krub, Elias Zerfu and Chimdo Anchala (eds). Enhancing the Efficiency of Agricultural Extension and Rural Development. Ethiopian Institute of Agricultural Research (EIAR). Addis Ababa.

Moti Jaleta, Paswel Marenya and Bedru Beshir2018. Does crop diversification reduce downside risk in maize yield-enhancing investments? Evidence from Ethiopia using panel data. 30th International Conference of Agricultural Economics, 28 August 2018, Vancouver. https://cslide.ctimeetingtech.com/icae2018/attendee/person/1334.

Truayinet Mekuriaw and Bedru Beshir 2018. Assessment of Tropical and Sub-Tropical Fruits Nursery development in urban and pre-urban areas in the Central Rift valley of Ethiopia. In: Eshetu Derso, Nigussie Alemayehu and Taye Tadesse (eds.) Results of Crop Research 2018. Proceedings of the National Conference on Completed Research, 9–14 October 2017, Addis Ababa, Ethiopia, pp.706 ISBN 978-99944-66-58-0.

Melkassa Agricultural extension research team were involved in the national large-scale demonstration assignment for six months. During the assignment, 10 technologies were demonstrated in five national regional states (Amhara, Tigray, Oromia, Southern Nations Nationalities People, and Benishangul Gumuz Regional State). Totally 81 clusters were established in 2218 ha of land by participating 4480 farmers.

Center level training, visit and experience sharing-coordination

Table 5. Number of trainers by gender

Visitors	Male	Female	Sum
Students	1199	912	2111
Teachers	76	15	91
Expert & DA	330	90	420
Farmers	57	18	75
Total	1662	1035	2697

Annually large number of visitors are coming to MARC. The visitors include students, teachers, agricultural experts and development agents. The programs mostly visited based on number of visitors is as follows: Fruits and vegetables, Agri-Engineering, Animal science (sericulture, apiculture and forages), Soil fertility and irrigation, Apiculture and sericulture, Agricultural economics and Food science and nutrition

Agricultural Engineering Research

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Agricultural Engineering Research process has been working on 11 government funded project (45 activities) and 4 external funded projects (6 activities). Those activities focus mainly on technology and information generation, evaluation of developed technologies, promotion/demonstration and multiplication of improved technologies, and training processers end users. Currently Agricultural Engineering Research Process is working on small horse power tractors and engines driven technologies to be availed by its two national programs. Agricultural Field Machinery Research Program and Post-Harvest and Product Processing Engineering Research programs are currently functional programs. Thus, this annual report is prepared to highlight the key finding of activities that has been executed in 2019.

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1. On station and on farm evaluation of 2WT-based conservation agriculture carried out using six seeders were imported from Brazil, Bangladesh, China, India and USA. The result indicated a 10-fold field operation time saving compared to the conventional tillage practice. Grain yield results also showed 29% and 22% increment in wheat and maize trials respectively. Among the tested seeders, VMP seeders performed best and selected as best-bets for both wheat and maize crops while 2BFG and John Morrison seeders performed best for only wheat seeding and maize seeding respectively. Fuel consumption of the seeders varied

from 9.36 liter per ha to 12.56 liter/ha depending on the type of attached seeder and depth of ripping (for zero till or ripping).

2. Once the best-bet 2WT attached seed drill for wheat was selected, improved/modified four-row 2WT attached wheat seed-drilling machine was developed locally as shown in Fig 1. using locally manufactured fluted roller seed metering unit. The metering unit can be used for planting mainly wheat and maize with minimum tillage. Based on the field performance evaluation for wheat, the planter has 0.16ha/hr. field capacity, 0.44 liter/hr. fuel consumption and can apply the desired rate of seed and fertilizer.

Fig 1.1. Developed 2WT tractor attached seed drilling machine

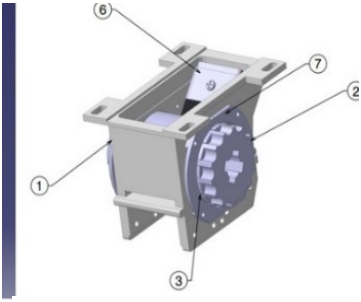

Fig 1.2. Fluted roller seed and fertilizer metering unit manufactured locally

1. Two versions of non-ground engaging seed drills for vertisol area were developed taking considerations of the safe carrying capacity of an average person and average walking speed of a single person. The first one is a front-pack manual seed drill with six row (20cm row spacing) and the other one is a shoulder held/backpack four row seed drills. Both seed drills use scoop type metering unit and seed application of the seed drills are done through making full rotation (360^0) of this metering unit (for the front pack type) and creating reciprocating motion (for the shoulder held type). Since the scoop type metering mechanism is adjustable, seeding rate was calibrated to give (4–5kg/ha) for both type of tef seed drill. The average field capacity of 0.14 and 0.09 ha hr^{-1} for

front-pack and backpack tef seed drill respectively was recorded and potential yield of 1892 and 2124 kgha^{-1} were obtained for backpack and front-pack tef seed drill respectively.

Field day were organized at two Kebeles (Shala Chabeti and Haro Bilalo) in Tiyo district Arsi zone, for creating awareness on 2WT attached wheat seeders, operation of 2WT and ancillary equipment through FACASI II project. As shown in Table 1, a total of 134 stakeholders were attended the event.

Table 1, Field day participant Shala Chabeti and Haro Bilalo Tiyo district, Arsi zone

Region	Farmer		Agricultural Bureau		Communication (journalist and their staff		private company		MARC		Total		Total
	M	F	M	F	M	F	M	F	M	F	M	F	
Oromia	83	13	16	3	4	-	3	-	11	1	117	17	134

1) Theoretical and practical trainings were given for end users. During the event 736 farmers, 377 agricultural experts, district agricultural development experts, and 4 artisans were participated.
2) Nine hundred and four technologies were multiplied and distributed to the end users.

Table 2. Technology multiplication

No.	Type of technology	Number
1	Animal drawn moldboard plow	250
2	Animal drawn tie-ridger	255
3	Animal drawn wheat row seed drill	5
4	Animal drawn tef row seed drill	10
5	Animal drawn ripper	165
6	Two wheel tractor drawn multi-crop seed drill	2
	Total	687

3) Quality assurance and technical support were given to the private companies participated in multiplication of some pre-harvest mechanization technologies which they were awarded through bidding process.

4) In collaboration with AGP-II project 1200 animal drawn moldboard plow were multiplied, training was given for end users, and batch produced plows were distributed to the farmers.
5) A short-term training was given for 4 researchers on workshop machine maintenance and electrical installation and 17 workshop technicians on newly installed workshop machines and their management
6) Completed research revenue was conducted where 12 research papers and reviewed.
7) A field survey was conducted in collaboration with KAFACI project on level of mechanization in Ethiopia were presented for south Korean researchers in Addis Ababa
8) A 3D printing machine that can help prototype manufacturing were acquired and CCTV Camera was installed in collaboration with FACACI project at Agricultural Engineering Research Process Manufacturing Workshop.
9) Seminars on public private partnership platform for scaling agricultural mechanization technologies were conducted.
10) Pre-harvest mechanization technologies (animal drawn moldboard plow and front pack tef row seed drill) were demonstrated to 50 organizations and 750 participants at third consultative meeting with stakeholders and first Techno Expo workshop organized by Ambo University.
11) Various pre-harvest mechanization technologies (animal drawn moldboard plough, ripper, winged plow, tie-ridger, multi crop row planter four wheel tractor attached ridger, multi crop planter, potato and potato digger, front pack tef row seed drill, manually operated lime spreader, two wheel tractor attached improved wheat row seed drill, harvester, multi crop conservation agriculture (CA) seeders, 2BFG-100 CA seeder, Fitarelli Two Row Multi crop Direct Seeder and Morrison CA-seeder Model 1000) were demonstrated for participants at 50 years anniversary of MARC.
12) Technical support and advisory service were delivered on pre-harvest mechanization technologies for various stakeholders.

13) Service was provided for stakeholders (farmers, private companies, manufacturers, non-governmental organizations, students and higher institution) visited Agricultural Engineering Research Process.

14) Training manual and module for operators focusing on operation, maintenance, and management of two-wheel tractor and calibration of ancillary equipment such as 2BFG seeder, trailer, pumps, threshers, and reaper harvester was prepared.

1) Frédéric B., Misiko M., Bisrat G., Nazzare R., Sariah J. and Kaumbutho P. 2019. Farm level assessment of labor and mechanization in eastern and southern. Agronomy for sustainable development. 39:17 Africa Journal of Springer Nature
2) Bisrat Getnet, Frediric Baudron, Girma Moges, Dereje Alemu, Desiye Belay and Teshome Bullo 2019. Evaluating two- wheel tractor attached conservation tillage seeders. In: Laike K., Bisrat G., Mulugeta T., Girma M. and Friew K.(eds). Results of Agricultural Machinery and Postharvest Engineering Research, 2018. Ethiopian Institute of Agricultural Research.
3) Girma Moges, Tamrat Lemma, Meseret Abebe and Laike Kebede (2019). Developing and testing tef drilling planter (2019).*In*: Laike K., Bisrat G., Mulugeta T., Girma M. and Friew K.(eds). Results of Agricultural Machinery and Postharvest Engineering Research, 2018. Ethiopian Institute of Agricultural Research.
4) Fitsum Abebe, Dessiye Belay, Tamrat Lema and Alayu Tilahun 2019. Developing and evaluating animal drawn multi crop planter. *In*: Laike K., Bisrat G., Mulugeta T., Girma M. and Friew K.(eds). Results of Agricultural Machinery and Postharvest Engineering Research, 2018. Ethiopian Institute of Agricultural Research.
5) Yonas Mulatu 2019. Performance Evaluation of Ground Wheel operated boom sprayer. *In:* Laike K., Bisrat G., Mulugeta T., Girma M. and Friew K.(eds). Results of Agricultural Machinery and Postharvest Engineering Research, 2019. Ethiopian Institute of Agricultural Research, Addis Ababa.

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Papaya, avocado and mango harvesters with two alternative designs were developed based on fruit weight, size and tree height. As a result, i) weight of the original papaya harvester reduced from 3.3 to 2.2 kg and operators found it very easy to handle and detach variable size papaya fruit from a tree height of 3-4 meter without imparting any mechanical damage to the fruit. ii) A new mango and avocado harvester were designed and fabricated. The field performance tests of avocado and mango harvester found to be efficiently, no damage working at the rate of about 2–3 fruits per minute

Three kinds of storage structures made of charcoal; scoria and rectangular hallow block as control were built and compared by watering the walls three times a day. The result indicated a significant difference among the structures in terms of temperature and humidity. Scoria (7.12°c and 8.5%) and charcoal (5.5°c and 7%) structures exhibited significantly higher humidity and lower temperature than the hollow block (4°c and 2.5%). In addition, a longer shelf life or delayed ripening (13 days) with a significantly ($p<0.1$) lower weight loss and spoilage of avocado fruit were recorded in the charcoal (10.7%) and scoria (9.38%) structures than the hollow block (18.75%).

Engine driven potato grading machine (Figure 1) capable of grading potato tubers into different size was designed, manufactured, tested and evaluated. The results indicated that grading capacity and fuel consumption of the grader increased with increasing cylinder speed and feed rate while

percentage mechanical damage and grading system efficiency decreased with increasing angle of inclination. The maximum grading system efficiency of 97.57 and 97.67% was observed, when the machine was operated at speed of 15rpm, angle of inclination of 5° and feed rate of 20 and 30 Kg.min^{-1}, respectively. At this optimum condition, the grading capacity, mechanical damage and fuel consumption were 1800.75 and 2000.46 Kghr^{-1}, 3.22 and 3.56% and 1.89 and 2.84 ml Kg^{-1}, respectively.

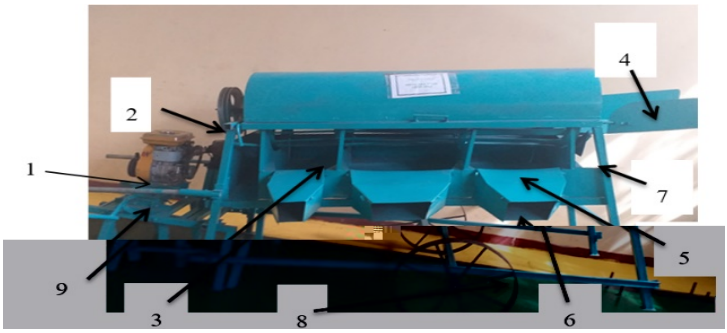

Figure 2. Prototype potato grading machine in operation; 1: Prime mover, 2: Pulley, 3 - Grading Cylinder, 4: Feeding Table, 5: Receiving Tray, 6: Outlet, 7: Frame, 8: Transportation wheel, 9: Handle

Depending on the demand coming from end users (farmers, wereda agriculture office, university, private company and others),, Postharvest Handling and Processing Engineering National Research Program multiplied a total of 217 harvest and post-harvest mechanization technologies (Table 1). Multiplied technologies were distributed to end users after training was given on the use and handling of multiplied technologies.

Table 2. Technology multiplication

Type of technology	Number
Metal silo 600kg capacity	54
Feed Chopper	35
Milk Churner	45
Papaya harvester	45
Potato digger	35

Tef thresher	1
Tomato seed extractor	2
Total	217

1. In collaboration with AGP II project 6 multi-crop thresher, 20 maize Sheller, 10 tomato seed extractor, 400 milk churner and manufactured and distributed by the center 400 metal silos of 1000 kg holding capacity were multiplied through a bid process.
2. Four common bean threshers and two metal silos were also manufactured in collaboration with CIAT/PABRA using TL-III project. During manufacturing; regular monitoring and quality control were done by staff members.

1. Training was given for 831 male and 300 female end users (pastorals, semi-pastorals, development agents, experts and technology manufacturers) selected from 24 districts. The training included use, handling and manufacturing of proven harvest and post-harvest technologies. Training was also given for researchers, technical and field assistance on workshop machine maintenance, electrical installation and workshop machine handling and operation for advanced machines.
2. With the help financial support from AGP II project small to medium sized enterprises business incubation for agricultural mechanization services were conducted. Rural youths, unemployed technical and vocational education graduates, university graduates and women groups living on selected AGP-II target districts; namely, Minjar-Shenkora, Baso-Worana, Tullu Bollo, Lume and Cheha districts were selected through sensitization workshops for creating awareness on overview, need and available technology options of agricultural mechanization service.
3. Theoretical and practical trainings were provided to 154 SME members and district experts at Melkassa agricultural research center, agricultural engineering research process. The trainings included sensitization,

business management, machinery operation, machinery maintenance and technical trainings.

4. Ten mechanization service providing business groups were established and nominated. In each district, one or more small and medium sized enterprises were established. Women groups, comprised of house wives, were also established. Five business groups purchased agricultural mechanization technologies and started giving mechanization services to the communities of their and nearby kebeles.
5. Nigus Asrat and friends harvesting, winnowing and related services is one of the successful SMEs established by the AGP-II project in Minjar-Shenkora district. The group members were trained and supported by professionals prior to getting into the business. Members were comprised of rural youths and farmers. The SME purchased three walking tractors and provided threshing service to local communities and neighboring kebeles. The location was a high potential area for tef and wheat crop production. There was a high demand that farmers get registered two months in advance to get the threshing service. In one threshing season, the group made 30,000 ETB, out of it 5,000 ETB was payed-out to cover running costs.
6. Regular monitoring, follow up and agricultural economists and researchers carried business model performance evaluation.
7. With the help of Farm Mechanization and Conservation Agriculture for Sustainable Intensification (FACASI) project field day was prepared on 2WT attached wheat harvester, thresher and trailer. During the field day, 95 stakeholders were participated on the event.
8. Post-harvest mechanization technologies (manually operated milk churner, maize sheller and metal silo) were demonstrated for more than 50 organizations and 750 participants at third consultative meeting with stakeholders and first Techno Expo workshop organized by Ambo University.
9. Various post-harvest mechanization technologies (two wheel tractor attached harvester and trailer, electric

driven milking machine, metal silo (different holding capacity), papaya harvester, cassava slicer, engine driven bean thresher, cleaning and non-cleaning type multi crop thresher, maize sheller, feed milling and mixing machine, sorghum thresher, feed chopper, potato grader, manually and electric driven milk churner) were demonstrated for participants at 50 years anniversary of MARC. Technical support and advisory were given on mechanization technologies for various stakeholders.

10. Internship training was given for eleven students coming from Ambo and Haramaya Universities for four months.
11. Agricultural Engineering team members participated in various committees in the center for example farm machinery and vehicles maintenance purchasing, discipline (maintenance and building).

1. Bisrat Getnet, Laike Kebede, Mulatua Wondimu, Fitsum Abebe and Teshome Bullo2019. Performance of Metal Silo and Purdue Improved Cowpea Storage Bag. Laike K., Bisrat G., Mulugeta T., Girma M. and Friew K.(eds). Results of Agricultural Machinery and Postharvest Engineering Research, 2018 Ethiopian Institute of Agricultural ResearchISBN:9789994466658
2. Laike Kebede, Bisrat Getnet, Yonas Lema, Mersha Alebachew and Melese Ageze 2019. Post-harvest processes and advances to introduce loss reducing technologies for rice. *In:* Taye Tadesse, Mulugeta Atnaf, Dawit Alemu, Tilahun Tadesse and Kiyoshi Shiratori (eds). Advances in Rice Research and Development in Ethiopia. Ethiopian Institute of Agricultural Research.
3. Friew Kelemu, Teshome Bulo and Mohamed Temam 2019. Evaporative cooling structures for storage of horticultural crops. *In:* Laike Kebede, Bisrat Getnet, Mulugeta Tamir, Girma Moges and Friew Kelemu (eds). Results of Agricultural Machinery and Postharvest Engineering Research, 2018. Ethiopian Institute of Agricultural Research.
4. Friew Kelemu, Teshome Bulo and Mohamed Temam 2019. Introduction of Naturally Ventilated Potato storage structure. *In:* Laike K., Bisrat G., Mulugeta T., Girma M. and Friew K. (eds). Results of Agricultural Machinery and Postharvest Engineering Research, 2019. Ethiopian Institute of Agricultural Research.

Animal Science Research

Apiculture and Sericulture Research Program

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Mulberry accessions were evaluated across locations. After successive selections, the best performing mulberry accessions namely K2 and S13 have been planted in 2019 for verification trial. These accessions were planted in four locations using appropriate procedures and evaluated by the National Variety Release Committee. The verdict expected in near future.

A study was conducted with the objectives to evaluate the agronomic and their rearing performance of different genotypes of castor on eri-silkworms. From last year selection, 30 best performing castor germplasms were planted and evaluated. Out of which six germplasms have been selected and advanced for further evaluation in different locations. Different silkworm strains and their feed plants (mulberry and castor) accessions/ variety maintenance was carried out. All the available accessions/varieties of feed plants and silkworm strains were maintained and evaluated under field and laboratory conditions. Cassava plant *(Manihot spp)* as an alternative feed for eri-silkworms was evaluated.

Cassava lines available in the country were collected and evaluated. Among them, the best cassava lines were planted and established well in four locations. Generally, it is proved that all cassava varieties were eaten by the eri-silkworms. Therefore, the best varieties in terms of biomass production and nutrition content will be known after completion of analysis.

Demonstration and popularization of silk production was initiated to effectively transfer knowledge and technologies among the different stakeholders for wider impact. Therefore, technologies such as improved silkworm races, silkworm

rearing techniques and improved silkworm feed plants were demonstrated for several visitors by providing them the associated information to develop awareness and knowledge about the technologies who were coming to MARC at different times.

Training was provided to 220 males 394 females beneficiaries on silkworm rearing, mulberry and castor feed plants growing and silk processing technologies. Apiculture & sericulture technologies pre-scaling where177 (60 males 117 females) honey bee and silk producers participated. Seven hundred forty silkworm layings, 9300 mulberry cuttings and 167 kg of castor seed were multiplied. Among 590 silkworm layings, 7,000 mulberry cuttings and 125 kg of castor seeds were provided for small scale and commercial farmers to enhance silk production. Twenty-six modern bee hives were distributed for small scale farmers to increase honey bee production and productivity.

Feeds and Nutrition Research Program

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1. A national variety trial conducted for one year across three environments (MARC, Mieso and Fentale-Gidara) both on-farm and on-station. Two candidate varieties from each of lablab and cowpea evaluated by National Variety Release Committee (NVRC) under Ministry of Agriculture has been officially released for commercial production under local name Doli-I and Doli-II for lablab and Melka and Adulala for the cowpea.
2. A multi-location experiment was conducted to select/ identify candidate forage sorghum variety with stable and high forage biomass production and *in vitro* organic matter digestibility with less talk thickness across different locations and years was completed in 2019. The experiment was carried out in a Randomized Complete Block Design with three replications at Mieso, Melkassa, Kulumsa and Negele Arsi sites. The data collected and summarized across locations and years showed significant differences among the 10genotypes tested for yield and quality aspects. There was statistically significant difference among genotypes for dry matter yield, maturity period, plant height, stalk thickness, CP, IVOMD and fiber contents. Hence, as consequences, at least two candidate varieties with high IVOMD content will be promoted to the next level of variety verification trial.
3. An experiment was established on evaluation of adaptation and yield performance of three commercial Brachiaria grass cultivars/ varieties introduced from Brazil via BecA- ILRI Hub was completed in 2019. All the three Brachiaria grass varieties (Pihta, Xares and Baslicks) showed good adaptation and outstanding performance in

forage yield with supplementary irrigation at both MARC testing sites (Melkassa and Gidara). There was significant difference in forage yield among the three varieties. Hence as a next plan, performance data will be submitted to NVRC for verification and decisions to be made if the varieties are to be allowed or not to be allowed for registration in Ethiopia.

4. With a USAID supported Livestock Systems Innovation Lab (LSIL) trilateral (EIAR-Kansas State University-Florida University) project on linking cattle nutrition to human nutrition, we conducted on-farm trials in Adama, Boset and Lume districts. In total, there were five farmers involved in the trial. The farmers were provided with different varieties of sorghum belonging to one of early or late maturity dual purpose (gran cum forage) varieties so far released for grain production. Four motorized operated feed choppers were also distributed to four of the farmers which they returned on finishing chopping the forage sorghum biomass produced. Field days were also conducted to demonstrate to other farmers and development workers. As a result, the on-farm trials were visited by 59 farmers, 29 development agents and experts as well as by 16 researchers. The Melkassa next year plan is to expand the demonstration work to reach to 100 farmers by the upcoming season.

Crops Research

Field Crop

Lowland pulse Research program

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In 2019 cropping season, the national lowland pulse research program was released four bean market classes with different merits.

1) NUA 517: Biofort Large Red mottled bean adaptable to moisture stress areas such as Central Rift Valley and similar agro- ecologies, tolerant to major foliar diseases high mineral content (Fe: 81.07ppm and Zn: 41.87ppm) and productive variety with grain yield up to 3t/ha.
2) SCR-15: Small red bean variety (SCR-11,) adaptable to moisture stress areas such as Central Rift Valley and similar agro- ecologies, resistance to foliar diseases, with higher grain yield than the check, with average yield performance (2.7t/ha)
3) SCN-11: black bean, emerging market preference which are adaptable to moisture stress areas such as Central Rift Valley and similar agro-ecologies. Resistant to foliar diseases and grain yield productivity 2.3t/ha.
4) RAZ 42: Small white bean adaptable to moisture stress areas such as Central Rift Valley and similar agro-ecologies, resistance to bean bruchids and also preferred seed color for international market.

The National Lowland Pulse Research program was also conducted three verification trials to release lowland pulse varieties with superior performance in productivity and disease resistance. The description of the candidates was as follows.

a. A cowpea variety which are drought tolerant, high yielding, disease resistance and with different seed color which can give diverse choice to the end user were

verified. These candidates are NLLP_CPC-145-21, NLLP_CPC-103B and NLLP_CPC-07-54. Genotype NLLP-CPC-07-145-21 found to give average grain yield potential up to 1970kg/ha, but this genotype found to have a potential to yield up to 3 t/ha at specific sites.

b. The second-best superior performing genotype was NLLP-CPC-07-54, with the average grain yield of 1848kg/ha but with a potential to yield up to 2.9 t/ha at specific sites. The third genotype NLLP-CPC-07-03-B was selected based on farmer preference with the productivity potential of 2t/ha.
c. Mung bean variety MB 6173-B-33 was selected due its internationally market and with average yield productivity 1.2 t/ha but with yielding potential at certain sites 1.9t/ha.
d. Cluster bean (Guar) *Cyamposis tetragonolobus* (L.) is a new crop in Ethiopia, which adapts well at semi-arid & arid areas which has high temperature. This crop adapts well at lowland areas which has up to 35°Cat cropping season and with productivity potential up to 2.5 t/ha especially at heat prone areas for example South Omo.

The National Lowland Pulses Research Program with the support of government and externally funded project were multiplied substantial amount of breeder seed and nucleus seed of recently released and demanded varieties in collaboration with other Research centers. The program also supports and facilitates the production of pre-basic, basic and certified seed by providing seed, technical support, information and organizing common bean stakeholder's platform. Accordingly, the production of different class of bean varieties was done by Melkassa, other collaborating center and public private institutions (Table 1).

Table 1. Amount of early generation common bean seed production (tons) by national common bean research team

Variety	Breeder	Foundation	Certified	Total
Tinike	1.3	4.4	0.0	5.7
Tafach/ SAB 632	0.5	0.0	0.0	0.5
SER 125	0.5	5.0	0.0	5.5
SER 119	2.9	12.5	134.5	149.9
Rori	0.0	14.5	15.0	29.5
Remeda	0.0	5.0	29.0	34.0
Nasir	2.1	79.8	2,074.0	2,155.9
Lehode	0.1	0.0	0.0	0.1
KAT B9	0.1	1.0	0.0	1.1
KAT B1	0.1	0.7	0.0	0.8
Ibado	0.0	5.0	0.0	5.0
Hawasa dume	1.9	36.5	1,226.6	1,265.0
Fetene	0.3	1.3	0.0	1.5
Dursitu	1.3	4.1	0.0	5.4
Derash	0.3	0.0	0.0	0.3
Deme	0.0	1.1	5.5	6.6
Chercher	0.6	6.5	0.0	7.1
Awash meten	0.1	0.0	0.0	0.1
Awash 2	3.9	67.6	895.0	966.5
Awash 1	0.4	30.6	175.0	206.0
Ado	0.3	0.0	0.0	0.3
Total	17.9	279.6	4,554.6	4,852.0

Foundation seed= pre-basic and basic seed

National common bean program has been engaging in multi-stakeholder innovation platform in collaboration with collaborative research centers and universities. The multi stakeholder platform members incudes: farmers, grain traders, policy makers, researchers, NGO's, corporative unions, public and private seed producers, traders, exports and ECX. Central Rift Valley multi-stakeholder meeting was conducted and from the meeting of these platforms a total 115 (M=95, F=20) participated and exchanged information on, seed production and business management, seed producers in post-harvest handling and value addition, importance of bio-fertilizer, crop protection technologies, post-harvest management technologies and mechanization technologies. In the future area-based platform meeting and engaging the

stakeholders will continue across the country to enhance the linkage and technology promotion of bean-based technologies.

The national lowland pulses research program, in collaboration with other partners and collaborative centers were engaged in enhancing the capacity of development actors (Bureau of agriculture experts, development agents), seed growers with the support of TL III/AGRA fund and in collaboration with another project and NGOs. The training was provided by different centers with financial and technical support by the national program and other projects. The detail of the training presented in Table 2.

Table 2. Training organized on common bean to MARC and Collaborative Research centers

Training place	Project collaborations	Number of participants		
		Male	Female	Total
Adama	TL III/Res. Extension	38	7	45
Adami/Tulu	TL III/ Res. Extension	42	8	50
Shalla	TL III/ Res. Extension	55	7	62
Hawassa	TL III/Hawassa ARC	60	14	74
Haramaya University	TL III/ Haramaya University	54	7	61
Areka	TL III/Areka ARC	25	5	30
Total		283	48	331

The National Lowland Pulse Program promotes bean-based technologies using demonstration trial, field day and printed materials using government as well as externally funded projects. Moreover, the program collaborates with different projects and NGOs to promote bean-based technologies. The program provides technical as well as seed support for these demonstration trials. Accordingly, a total of 2348 demonstration trials were conducted on farmers' field in collaboration with different projects partnering the program (Table 3). Moreover, a total of 355 different partners were also visited the demonstration trials on demonstration & seed multiplication sites in collaboration with different stakeholders and projects (Table 4).

Table 3. Demonstration &participating farmers conducted in collaboration with partners

Partner/Organization	Type of Demo	Number of Demo
BENEFIT-REALISE (Haramaya University)	Crowd sourcing	808
BENEFIT-REALISE(Oda Bultum University)	Crowd sourcing	30
(Haramaya University)	Crowd sourcing	650
ISSD-SNNP	Crowd sourcing	800
SG-Africa	Demo trial	50
Melkassa	Cluster seed production & demo	10
Total		2348

Note: BENEFIT-REALISE= Realising Sustainable Agricultural Livelihood Security in Ethiopia' (REALISE) ISSD=Integrated Seed Sector Development; SNNP= Southern Nations and Nationalities and People; SG=Sasakawa Global

Table 4. Number of field days conducted with partners in lowland pulses and participants

No	Field day areas	Male	Female	Total
1	Adama	90	20	110
2	Adamitulu	70	9	79
3	Shalla	101	14	115
4	Negele Arsi	70	9	79
5	South Wello	36	6	42
	Total	297	58	355

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Maize Improvement for Drought Stress, Heat Prone and Irrigated Areas

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Low moisture, heat stresses and irrigated maize research has been doing research since its establishment in 1993 GC. The major research disciplines are breeding and genetics, Crop management (Agronomy), Crop Protection and Agricultural Extension. In 2019; 32 different activities were proposed to be accomplished out of which 14 activities were conducted under the breeding components, 3 activities under Agronomy project, 2 activities under Extension activities handled by (Chiro and Mehoni Agricultural Research Centers 8 Activities registered as collaborative work which were received from EIAR Centers mainly Bako national maize, Hawassa and Ambo Centers, 2 activities were from Seed Companies (Monsanto and Pioneer) and 2 Activities were PhD Dissertation work.

Two candidate hybrids varieties evaluated across six locations by the National Releases Variety Committee and waiting for their decision which was significantly delayed by Covid-19. Candidate1 (MH141 or WE7210) had an average yield of 7.39ton ha^{-1} over eleven environments (Year X Location) with a yield advantage of 37.7% over MH140 (5.37-ton ha^{-1}) whereas Candidate 2 (MH142 or WE8216) had an average yield of 7.97ton ha^{-1} over the same environments and holds a yield advantage of 48.42%.

In terms of seed production and distribution, from our previous year stock and 2019 production we managed to produce 4300kg of breeder seed of ten different varieties and distributed 3200kg to different stakeholders including seed companies, higher learning institutions, regional Bureau of Agriculture s, Agricultural Research Center Technology production units, students, NGOs and individual farmers.

in 2019 cropping season, 14 activities were conducted under the breeding components. The activities were majorly of Introductions as well as locally generated hybrid evaluations conducted through government budget and small grant funds (STMA, NUME and AGRA and MERCI projects). In addition, 3 field activities on CFT site and irrigation facility development was conducted by WEMA project. MERCI project has been supporting the breeding project in general to modernize it and increase its efficiency. It has no registered well-defined activities but it has been involved in 10 capacity development activities which are also supported by the government fund; apart from some small fund provision in the breeding and variety evaluation areas. The locations for the evaluations include: Melkassa, Dhera, Werer and Mieso whereas the human resources were 4 researchers and 7 field assistances.

MERCI has been supporting us strengthening our capacity and efficiency of our breeding program in ten different aspects which involves data management and mechanization. Recently we managed to build one new cold room as well as maintenance was done for an old cold room which increases our total cold rooms to three. The other thing is we manage to use maize plot thrasher which increased our accuracy and efficiency significantly which was also contributed by MERCI. WEMA project is also providing capacity development in establishing Confined field trials site (CFT) along with drip irrigation facilities.

A total of 871 hybrids from introductions and local breeding nurseries (QPM and CM) were evaluated on 2-5 locations. Among the evaluated hybrids and OPVs 131 of them showed a 10% yield advantage over the local check were selected. The selected hybrids and OPVs were included under different activities (trial stages) in the coming new project. In order to generate hybrids from the local crossing program 438 lines (QPM and CM) were utilized in test cross formation, regeneration, per se performance evaluation under this product concept.

ANOVA showed that the genotypes performed very differently across the three locations and the candidate varieties showed yield advantage of 23% (WE7210) and 30% (WE8216) apart from that the yield potential of the inbred lines were also evaluated and showed that a yield potential ranging from 1.5ton ha^{-1} (WMB20001) to 3.3ton/ha (WMB4846) at Melkassa and Miesso which was also a good characteristic for seed producers (Table 2). At the same time the flower synchronization study showed that there is no need to do staggering in planting for seed production of both the single crosses as well as the hybrids themselves which was also another important advantage.

Seed production in 2019 reached 4300kg of breeder seed of ten different varieties and managed to distribute 3200kg to different stakeholders including seed companies, higher learning institutions, regional Buraus of Agriculture, Melkassa Agricultural Center Technology production units, students, NGOs and individual farmers.

Sorghum Improvement Research Program

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Over years, sorghum research particularly improved variety development efforts have been conducted by dividing the sorghum growing environments into four major traditional agro-ecologies; dry lowlands, humid lowlands, intermediate altitude and high elevation areas. Research efforts have been conducted to develop technologies suitable for these agro-ecologies. The dry lowland agro-ecology is the vast majority sorghum growing area of country and mostly characterized by erratic rainfall, low soil fertility and fragile eco-system. The major constraints of this agro-ecology are drought, striga & stalk borer and since recent times fall armyworm and hence research emphasis has been given developing drought tolerant and striga resistant sorghum varieties which can escape the early cessation of rainfall. For the year 2020 three potential candidate genotypes were identified for dry lowland sorghum growing environments to be verified in 2019.

Figure 1. Released early maturing and high yielder sorghum varieties for dry lowland agro ecologies in 2019.

Appropriate seed delivery mechanisms like seed mini packs were devised and promoted. Strategies for disseminating improved technologies like training of extension staff and farmers, distribution of small packs, on farm demonstration, cluster based large on-farm demonstration and field days were used. To create awareness and demand on the recently

released sorghum and finger millet varieties a total of 200 demonstration plot were established in Oromia, Amhara, Tigray, South and Benishangul regions. A field day, famer to farmer field visit and field tour was successfully accomplished to transfer experience of those farmers engaged in use of sorghum to other farmers not yet fully engaged to use the early maturing and high yielder sorghum varieties to ensure their food security. In sorghum and finger millet technology out reaching 18,377 male and 3663 female farmers have been involved in major sorghum and finger millet growing regions mainly Amhara, Oromia, Tigray and Benishangul national regional state. To reach this number of farmers small seed pack has been used in 1kg and 2kg.

In the year 2019 cropping season, 550qt of breeder and more than 500qt of pre-basic seed has been multiplied in at different research station through the support of Harnessing Opportunities for Productivity Enhancement (HOPE II) of Sorghum and Millets in sub-Saharan Africa – Phase-2 and integrated striga control (ISC-II).Intensive training has been given on sorghum OPVs and hybrid seed multiplication for both the formal and informal seed growers (i.e., Oromia, Amhara, Oromia, South seed enterprise, Tigray seed unit, Sirinka, Shire Mytseberi and Fedis research centers. community based seed multiplication scheme has been implemented in different areas to create access of the best preferred improved sorghum varieties.

Figure 2. Cluster based seed production of improved sorghum variety in Gololcha district in 2019/2020

To improve the uptake and adoption of improved sorghum varieties training has been given on sorghum production package and seed production to 2011 male and 601 females. A total of 2612 farmers, development agents and agricultural experts selected from four major sorghum growing national regional states(Oromia, Amhara, Tigray and Benishangul were participated in the training.

Research capacity development (long- and short-term training for researchers): To strengthening the human and infrastructure facility of the sorghum research in Ethiopia short term training has been provided to researchers and technician selected from 13 regional research centre, 7 EIAR and three universities. For long term training 4 MSc and 5PhD students selected from EIAR centres and regions joined university to attend their post graduate with the support of external and government funded projects. A total 25 male and 5 female researchers and technician have been trained on the undermentioned topics.

1. Product concept and pipelines development (breeding pipelines optimization)
2. Trial and genotype naming conventions
3. Overview of Electronic data capture, field book Preparation and trait validation & Some useful excel functions
4. Electronic data capture theory and practice (Field Scorer and Kombine)
5. High light of digital plant height and plot yield measurement
6. Bar-coding, Mail merge, packet printer and automatic seed weighing (Konnect) theory and practice
7. Application of appropriate experimental designs and analysis models
8. Molasses Trap for insect control (folly army worm, stalk borer and other related
9. Sorghum biology and phonology
10. Finger Millet Research and Development in Ethiopia: Opportunities and Constraints

11. Hybrid Sorghum Research & Production in Ethiopia
12. Researcher attributes, Paper publication and grant writing

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a. One researcher from National Sorghum Research participated in sorghum scientist field day held on 14-15 February 2019 at ICRISAT, Patancheru, Telangana, India
b. Training have been given for Oromia, Amhara, South seed enterprise and Tigray seed experts on sorghum seed production and quality inspection
c. Short term training provided for Holeta, Kulumsa, Sinana barely breeder on advanced data management tools (Field's corer, Kombine, barcode reader & digital balance)
d. Advanced training on multidisciplinary product development provided for pathologist, food science and nutrition researcher at head quarter.
e. Advanced Statistical training was given for breeders in May 2019.

- Supervise 2 MSc and 2 PhD students

- Technical backstopping to private seed producer on sorghum hybrid
- Technical backstopping for Oromia, Amhara, South seed enterprise on sorghum seed production.

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1. A construction of new cold room using the financial support of ISCII & MERCI projects
2. One plot thresher (Kobo), 2 digital balance, 3 tablets, 41,000 packets (Melkassa), 4 lap top computer purchased and distributed to support the sorghum implementing Centres
3. Centrifuge purchased for food science
4. Refrigerator purchased for pathology research division
5. Packet printer maintained
6. Asrmel-4R license purchased and installed

Agronomy and Crop Physiology Research Program

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Field experiment was conducted to evaluate three lowland beans compatibility to intercropping with two lowland maize varieties. The experiment was laid out in a randomized complete block design with three replications. The two years research result indicated that there was a significant ($P<0.05$) yield difference among the treatments. Intercropping of maize variety Melkassa-4 with Awash-2 and Deme has given relatively higher bean yield at Melkassa and Negelle Arsi during the two experimental seasons. At Mieso maize variety Melkassa-4 with KAT-B1 gave higher yield in the first season. But in 2019 due to the extended rain fall at this area the early maturing KAT-B1 performance was low. System productivity analysis indicated difference in the land equivalent ratio (LER) among the systems in all site-season combination. Those treatments with LER values > 1 indicated that intercropping of bean varieties with maize has an advantage than practicing bean sole cropping. Therefore, from the result obtained it can be concluded that bean variety Awash-2 and Deme are suitable to intercrop with Melkassa-4 maize variety at Melkassa and Negelle Arsi, and at Miesso these varieties can be grown with Melkassa-1.

Field trial was conducted at Melkassa and Werer on twelve large seeded bean varieties and nine small seeded bean varieties as a separate experiment to clearly identify which variety will suit for irrigation production. Results showed, from the small seeded genotypes Awashe-2 resulted

significantly higher grain yield (3426.8kg ha^{-1}) under the irrigated system. From the large seeded bean varieties, Cranscop and Goberasha gave relatively higher yield. Pod clearance from the ground is one of the parameters for selecting the varieties as the best fit for irrigation production, and this parameter showed significant differences between the varieties. Deme and Melka Dima recorded higher pod clearance while KAT-B-9, KAT-B^{-1}, Awash Melka and Awash-2recorded the lowest distance from the ground to the tip of the pod.

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Three water regimes were combined with three rows spacing in complete factorial to identify appropriate row spacing for irrigated mung bean production at different locations in Ethiopia. Trail was conducted at Melkassa and Mehoni using mung bean variety N-26with split-plot arrangement of three replications. Necessary data were collected and analyzed to identify best spacing and irrigation rate for mung bean production in the lowlands of Ethiopia. The result indicated that except the pod length all parameters considered were significantly ($P<0.05$) affected by the irrigation rate. The highest grain yield was recorded from 75% water regime (35% deficit irrigation) and the effect of row spacing was not significant on mung bean performance under the three water.

The effect of nitrogen rates (four rates) on bean and maize were studied at Melkassa under different cropping systems (four types) and tillage types (two types). The experiment was laid out in split-split plot with three replications with tillage assigned to the main plot, cropping system to the sub-plot and N rate to the sub-sub plot. Pre plant composite soil

samples were collected and analyzed for soil physical and chemical properties. Crop data were analyzed for growth, yield and yield related parameters. Maize and bean yield and all the other parameters recorded were not affected by the interaction effect of factors. But maize and bean yield and yield components were significantly affected by the main effects of tillage types, nitrogen rate and cropping system.

Growth parameters like LAI was not affected by the main effects of tillage, nitrogen, cropping system and their interactions. The SPAD reading (chlorophyll) was significantly affected only by the main effect of nitrogen fertilizer rate. The highest maize chlorophyll (SPAD) concentration was from 61 kg N ha^{-1} rate followed by41 kg N ha^{-1}. Furthermore, yield and yield components of maize were significantly affected by the main effects of nitrogen rate. But only grain yield was affected by the main effects of tillage and cropping system. Grain yield was greater with conventional tillage and sole maize cropping system though higher land productivity was from maize-bean intercropping system. Except the grain yield all growth, yield and yield related parameters of common bean were not affected by the main effect of tillage (Table 2). Bean grain yield was greater with conventional tillage practice (CP) compared to conservation tillage (CA). Yield and all yield related parameters were significantly affected by main effects of cropping system and nitrogen fertilizer rates. Stover, biomass and grain yield of common bean was higher for maize-bean rotation and sole bean as compared to maize-bean intercropping.

Two maize varieties were validated for new plant densities in 3 districts on a total of 10 farmer field and two FTC with a plot size of 10m x 20m. Higher grain and biomass yield were attained for denser plant population (61500) across all the tested locations with better farmer perceptions for the denser plant population. Irrespective of the crop varieties and

locations the new plant population density of 61,500 plant/ha had given better yield advantage over the previously recommended density (53,333 pt/ha). The new plant population density (61,500 plants ha^{-1}) gave 19.25 and 20% grain yield and 16.12 and 12% Stover yield advantage over the recommended density (53,333 plant/ha) at AJ, Bofa and Dugda, respectively. It also gave 18 and 28% grain yield and 6 and 23% stover yield advantage for $MH^{-1}40$ and Melkassa-2 maize varieties, respectively.

The experiment was conducted as planned at Mieso and Fedis and the trial will be completed by 2020. The objective was to assess productivity of crop intensification options through incorporating different legumes into the sorghum-based system and to determine the trade-offs between economic return-risks of double cropping systems. The experimental design was a split-plot with cropping systems as main plots and three rates of N fertilizer application as subplots. Overall, our results show that the double cropping systems resulted in higher sorghum grain yield at both study sites in both Mieso and Fedis compared with sorghum monocropping.

Response of hybrid sorghum to plant density and NP fertilizer rate were studied. The objectives were to determine optimum plant density and application of inorganic N and P fertilizer rates for the recently released sorghum hybrid. The experimental design was arranged as a factorial combination of three treatments in randomized block design (RCBD). Treatment combination included: five nitrogen level (N; Kg ha^{-1}): 0, 23, 46, 69, 92; three phosphorus level (P; kg ha^{-1}): 0, 20, 40; and two plant density (PD; plants ha^{-1}): 66,600 and 88,800. Analysis of result showed only the main effect of year,

nitrogen and plant density was significant for grain yield. The quadratic response to the main effect of N was also significant. The grain yield increased consistently up to 40 kg N ha^{-1} and start to drastically decline beyond that level. The three-way plant density, ´N, and P interaction was not significant, and neither were any of its linear, quadratic polynomial responses. The non-significant three-way interaction may have been due to the almost parallel response of grain yield at each of the PD for all levels of N rates and at all P rates. Similarly, the response of grain yield to all P rates for each of the two PD and five N rates didn't show any cross-over effect or any change in magnitude across levels tested. In this data set, the two-way interactions (N×P) were significant. Any conclusions depending on only main effects or combinations of main effects cannot be drawn when pertinent crossover interaction (COI) or interaction because of treatment rank change are significant. In this study, inconsistent responses to the P treatment relative to the different levels of N due to [COI]) (Fig 3b). Similarly, the two-way interaction of yr. and P was significant including the linear and quadratic responses of P in the year x P interaction. This shows that the response to the application of P is season-dependent.

Field experiments where designed and conducted to study the influence of management predictors (planting configuration: full configuration and single skip; stand density: normal and dense plant population; N fertilizer level: 0N and 50N kg ha^{-1}); environmental predictors (soil type: plant available water content; PAWC plus fertility status; rainfall during the crop cycle; and genotype predictor (LAI of different genotypes). The experiment was conducted at three widely spread area in the semi-arid rift valley region in Ethiopia. Initially, all statistical tests were performed using the ASReml package (Butler et al., 2007) in the R environment (R Core Team, 2017). The linear

mixed-effects models conducted to assess the influence of different predictor variables on grain yield. Residual maximum likelihood estimation was used to model variance in the response of total biomass, yield, grain number and weight, and tiller yield, for each trial to structural (block) and fixed (treatments and their interaction) effects (α=0.05).

Two separate experiments were conducted. The treatment factors for the on-station study consisted of two plant densities (66,666 and 88, 888 plants ha^{-1}), two early-maturing varieties (cvs. Melkam and Argity) and three NP fertilizer rates (0 N – 0 P, 23 N – 10 P, and 46 N – 20 P kg ha^{-1}). The FTS experiment included: 1) old locally adapted variety (cv. Melkam) along with current local farmers' practice; 2) newly released variety (cv. Argity) along with the current farmers' practice; and 3) new variety (cv. Argity) in combination with a row planting at 88, 888 plants ha^{-1}, and fertilizer application of 41 N and 16 P kg ha^{-1} along with tied-ridging for soil moisture retention. A three-way analysis of variance (ANOVA) was done to evaluate the effect of plant density, cultivar and NP fertilizer on phenology, biomass and grain yield and its component on-station. The ANOVA combined over locations has an expanded model that includes location effects and interactions. For the combined ANOVA analysis across the tested locations, the results showed that all the traits were affected by the main effects of location and variety, except for days to maturity. The only effects that were not significant for any of the traits tested were the main effect of plant density (PD), two-way interaction of VxNP, and the three-way interactions of Location (Loc) x PDxVariety (Var), LocxPDxNP and Loc x Var x NP. The three-way PD x V x NP interaction was not significant. The grain yield was affected by the main effect of variety (V), NP fertilizer rate (NP), and by the two-way interactions of location (Loc) x plant density (PD), Loc x V, LocxNP, PDxV, and PDxP. The lack of V x NP interaction was

due to near parallel response of the varieties to the application of fertilizer even though yield levels differed. While statistically significant, the three-way interaction of PD x V x NP was not of agronomic significance as it accounted for less than 1% of the treatment-related variation in grain yield while NP rates overall accounted for 46% of the variation. Soil properties, rainfall amount or distribution, planting date, and previous crop were not related to the maximum trial grain yield, the yield without fertilizer, yield responses to applied NP, or the economic profitability. The results do not indicate that site properties can be used to estimate the economic benefit of fertilizer on a site or site-season basis. The soil test results indicated that response to applied P was unlikely at Sheraro and Kobo while a response at Erer might have occurred with a higher yield level.

The FTC trial at Fedis was not harvested due to security reason and only the result from Kobo and Sheraro sites were combined for evaluating the locally adapted variety along with the traditional practices against to the newly released variety, cv. Argity. Yield responses due to N-P fertilizer was calculated from yield differences between treatments. Economic returns, expressed as value to cost ratio (VCR, birr/birr), was calculated by first multiplying crop price at local market and yield response and then dividing the value by costs of applied fertilizer. The analyses of variance were conducted using GenStat 12th edition (VSN International, Hemel Hempstead,

($p<0.05$) at Sheraro. That is, grain yield was 33% more with cv. Argity compared to the locally adapted cultivar, cv. Melkam when both varieties grown under local farmers practice. Using the recommended practice along with cv. Argity, grain yield was significantly increased by 8 to43% compared to the local practices for cv. Melkam and cv. Argity, respectively. The average agronomic efficiency of applied NP fertilizer (kg increase grain yield per $kg^{-1}$of NP applied) was 12, which range from 4.3 to 18.7.

As part of simulation modeling run for environmental characterization activity, weather data of the recent five years of Kobo and Sheraro was collected and cleaned before it was annexed to the existing database of "iMashilla" project for APSIM use. The soil water related data of Erer site was determined and this will be used for characterizing the area as one of the key sorghum multi-trial sites. The destructive plant sample and yield data from field trials at Erer, Kobo and Sheraro in 2019 will be used to setup APSIM for the purpose of better understanding the type of environment experienced in terms of water availability or determining the typical drought patterns for specific sorghum adaptation analysis through exploring the productivity–risk trade-offs for the combinations of genotype and management options in different environments. This will help in identifying optimal genotype and management combinations to realize seasonal yield potential in different environments.

Climate, Geospatial and Bio-metrics

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Prior knowledge on the starting dates and lengths of dry spells has a significant importance in rain-fed agriculture, irrigation planning, and various decision-making processes related to climate. In humid countries the success or failure of the crops, particularly under rainy conditions is highly related with the distribution of dry spells. For achieving maximum benefits from dry land agriculture, the knowledge of distribution of dry spells within a year is useful. The information on the length of dry spells could be used for deciding a particular crop or variety in a given location, and for breeding varieties of various maturity durations. Information on dry-spell lengths could be used in decision making with respect to supplementary irrigation and field operations in agriculture. The longest period of several long spells is of crucial importance in planning agricultural activities and managing the associated water supply systems. The following graphs shows chance of 5, 7, 10- and 14 or more-days dry spell risk at Ziway, Meiso, Dhera and Melkassa stations respectively.

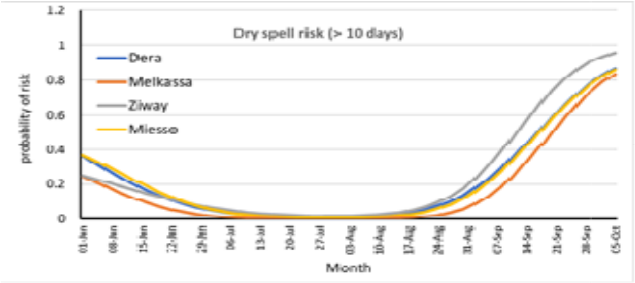

Figure 1. Chance of 5, 7, 10 and 14 or days dry spell risk at Batu (Ziway), Meiso, Dhera and Melkassa stations

The onset of a given season is the possible start date of rainfall in a year, whereas cessation is defined as a period which a rain ends in the season. The start of the season is calculated by combining spell length and cumulative rain over a specified consecutive day. Based on this, onset date for the cropping season is the first occasion of the rain with more than 15 mm in a 2- or 3-day period of rain since the start of the season and no dry spell of 10 days or more within the following 30 days. The number of rainy days was also calculated for days which daily gauge rainfall is greater than or equal to 0.2 mm.

Table 1. Onset, cessation and LGP of the study sites

Station	Onset of rainy Season			Withdrawal of rainy season			Length of rainy Season		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Dera	182 (30-Jun)	17.5	9.5	269	19.9	7.3	86.3	27.3	31.2
Miesso	185 (2-Jul)	17.2	9.2	273	19	6.7	88.1	23	26.0
Melkassa	179 (27-Jun)	13.2	7.3	275	11	3.9	95.9	17	17.1
Worer	192 (10-Jul)	14.8	7.2	256	10	3.8	64	17	26.7
Ziway (Batu)	177 (25-Jun)	18.8	9.9	262	13	4.8	84.7	23	26.4

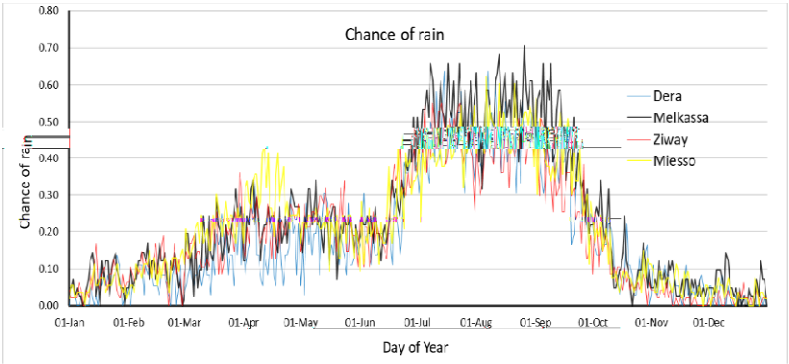

Figure 2. Chance of rain at Ziway, Meiso, Dera and Melkassa stations (based on historical rainfall data)

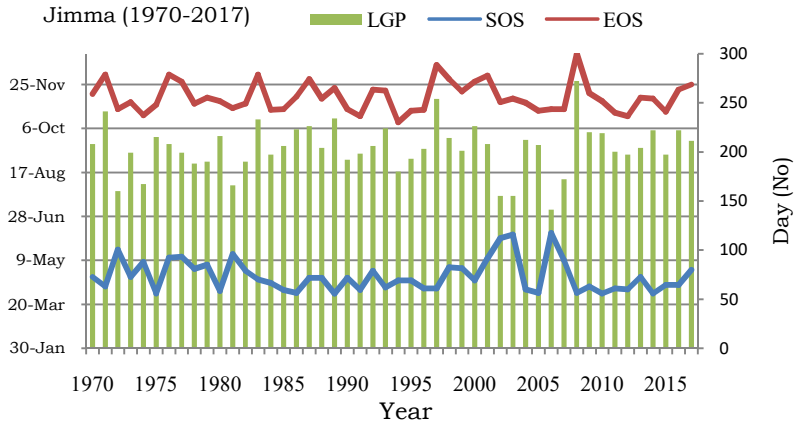

Figure 3. Seasonal rainfall characteristics of Jima station (based on historical rainfall data)

Genotype-specific coefficients for five dry lowland sorghum varieties were estimated using generalized likelihood uncertainty estimator (GLUE) tool embedded at DSSAT v4.7. It is a Bayesian estimation method that uses Monte Carlo sampling from prior distributions of the coefficients and a Gaussian likelihood function to determine best coefficients based on the data that are used in the estimation process. The GLUE program will make 3,000 simulation runs for phonology coefficients and another 3,000 runs for growth coefficients. The program randomly generates parameters that are being estimated (either phonology or growth) from the prior distribution of parameter values and runs the model for each. The model outputs are used to select the parameter set with the maximum likelihood value based on comparison of simulated vs. observed variables, first for phonology parameters, then for growth parameters. The program also computes the uncertainties of the estimates (variances) for each parameter. Four years experimental data collected at Mieso agricultural research experimental station were considered. The estimated genetic coefficients were expressed in terms of thermal time (degree days) and critical

photo period (in hour) from one growth phase to the other growth stages.

The following table shows estimated genotype coefficients for five sorghum varieties. To estimate those genotype coefficients, the experimental data undertaken from 2011 to 2014 major growing season were considered. Together with experimental data, the soil, weather and management data were used for estimation. The two tables listed below are also shows the estimated coefficient parameters

Table 3: Estimated Genetic Coefficients for sorghum cultivars

Genotype	Genotype specific coefficient parameters										
	P1	P2	P2O	P2R	PAN	P3	P4	P5	PHI	G1	G2
ESH-1	265.3	102	13.12	169.3	617.5	356.4	80.28	541.1	49	8.233	6.275
ESH-2	250.5	102	13.68	253.1	617.5	141.2	82.14	553.4	49	11.98	5.43
Teshale	333.6	102	13.71	277.9	617.5	362.7	90.88	545.8	49	2.266	5.558
Melkam	348.2	102	13.33	112	617.5	388.2	81.64	530.8	49	0.106	6.324

Table 4: Estimated Genetic Coefficients for Maize cultivars

Cultivar Name	ECO#	P1	P2	P5	G2	G3	PHINT
		1	2	3	4	5	6
BH140	IB0001	222.5	0.189	961.6	880.9	11.11	75
BHQP542	IB0001	238.1	0.810	941.6	857.9	16.46	75
Melkassa-2	IB0001	151.1	1.751	871.2	444.5	16.30	75
Melkassa-4	IB0001	149.7	0.719	865.7	875.2	15.04	75
Melkassa6Q	IB0001	155.2	1.633	873.6	968.7	15.91	75

Agro weather advisory is telling about when to prepare land, when to sow, when to apply fertilizer and how much, which variety to plant, what management practices to undertake for minimizing risk and maximizing the production under seasonal rainfall uncertainty. Climate and geo-spatial team of MARC collaboration with CIMIT by Capacitating African Stakeholders with Climate Advisory Services and Insurance Development (CASCAIS-II) project produce seasonal forecast and advisories on choice of crops and varieties as well as better agronomic management practices including dates for land preparation, planting, fertilizer applications, weed control, pesticide use, irrigation and other critical information to farmers in selected Kebeles in Arsi, East Shewa, West Shewa, and Hawasa zuria. The following tables show some of Decadal Climate Forecast and Advisory format.

Table 4. Decadal Climate Forecast and Advisory Melkassa site

Forecast period	Forecast	Action (farmers advisory)
Nov 21-30,2019	○ Untimely rainfall is expected from 22-26 Nov (Friday to Sunday) followed by dry conditions. ○ The chance of rain is high on Saturday and Sunday. ○ The total expected rainfall during this decade is 70 mm. ○ ○ Maximum temperature: 19.9 to 23.2 °C. ○ Minimum temperature: 15.5 to 16.8°C. RH values will range between 41- 90% but will remain between 65-80% for most of the days. Wind Wind speeds may be in the range of 4-18 km/hr.	The untimely rain in the next three days is a problem for harvesting maturing crops such as haricot bean and teff. Advice farmers not to harvest crops during the rainy days indicated.

Table 5. Decadal Climate Forecast and Advisory Tiyo (Assela) site

Forecast period	Forecast	Action (farmers advisory)
Dec 1-10, 2019	Rainfall: ○ Dry conditions will dominate until Dec 9. ○ Some rain showers may start starting on Dec 9. ○ Temperature: ○ Maximum temperature range: 20.0 to 23.0oC ○ Minimum temperature range: 11.1 to 14.1oC ○ Relative humidity (RH) ○ RH values will remain between 40-70%; but remain below 60% for most of the days. ○ Wind: ○ Wind speeds may range between 6 to 26 km/hr	○ Advice farmers to harvest and thresh crops before Dec 9th, ○ Untimely rain showers may start as of the 8th of December. ○ Market information at Assela market in the last few weeks: ○ Wheat: ○ 1400 – 1500 birr (whole sale) ○ 1600 – 1650 birr (retail) ○ Teff: ○ White teff: ○ 2800-2800 birr (WS) ○ 2900 – 2950 birr (retail) ○ Red teff: ○ 2600 -2650 birr (WS) ○ 2800 – 2800 birr (retail) ○ Mixed teff: ○ 2650 – 2700 birr (WS) ○ 2800 – 2800 birr (retail)

Climate data is a basic requirement in any research program therefore inspection of instruments for replacement and maintenance have been made for selected EIAR weather stations during January to December 2019. This ensures climate data generation and archiving for sustained use.

Table 6. Instruments provided for selected EIAR weather observatory stations during report period

Instruments	Quantity	List of weather stations
Thermometer for air temperature	6	Debre Zeit, Alem Tena, Asosa, Haru and Ambo
Soil thermometer	4	Ambo
Stevenson screen (shelter)	1	Tepi
Sunshine card	3000	Ambo, Tepi, Jimma, Debrezeit, and Kulumsa,

Horticultural Crop Research

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1. In 2019 cropping season, one red onion variety (called Violet De Galmi- with local Name Nafid) adaptable for warmer area released for irrigated production from warm season vegetable crops research program.
2. In the introduction and adaptation study of commercial varieties; in collaboration with Reliable Horti Consult PLC, one hybrid hot pepper and two sweet pepper for green pod production, one tomato, two water melon, and one head cabbage hybrid varieties were registered for private and commercial production and use.
3. Among the six candidate varieties evaluated by NVRC two pepper (Challa and Gebaba), two okra (Wayka and Beles) and one summer squash (Zucchni-1) varieties were released.

From determination of optimum plant population density for onion seed yield and quality, optimum plant population density for onion seed production was determined. Based on the partial budget analysis, treatment combinations 60x10, 40x30 and 40x10 were superior with respective net income of 1,126,675, 557,324 and 650,000 Ethiopian Birr at Melkassa, Kulumsa and Worer respectively. Therefore, it could be concluded that Bombay Red onion variety could be planted at optimum spacing of 60x10, 40x30 and 40x10cm spacing at these respective locations to attain financially feasible onion seed yield.

Table 1. Vegetable Breeder seed multiplication and distribution (kg), 2019

Crop	Varieties	Multiplied	Distributed
Onion	Nafis, Nasik red, Adama red, Robaf, Bombey red	94.23	103.36
Tomato	Gelilema, Chali, Melka shola, Melkasalsa, Cochoro, ARP tomato D2, Bishola	27.93	4.82
Pepper	Mareko fana, Melka awaze, Melka oli, Melka dera, Melka zala,	47.63	17.06
Amaranths	Mahdira-II, AC-NL		6.94
Snap bean	Platie, BC4.4	50.00	3.10
Pak choi	Sefisa-1, Sefisa-2		0.38
Chinese cabbage	Mi'o-1, Mi'o-2		7.32
Sum		219.79	142.97

A number of subject matter specialists, students, development agents and farmers were trained on improved production technologies of Vegetable crops. Researchers from different research centers and universities were also got experience and trainings on research methodologies, trial field management, nursery management, seed production and data collection techniques (Table 2).

Table 2. Major Training, Visit and other Services delivered by Vegetable Research Team of MARC, 2019

No of participants		Type of Service delivered	Organizer/Requested by	Service Delivered location	Clients Come from
Male	Female				
147	36	Practical and theoretical training	MoA	Melkassa ARC	From all regional offices
120	45	Training	MoA	Alage TVET	
27	32	Field visit	Arsi University	Melkassa ARC	Arsi university
28	30	Field visit	Asosa University	Melkassa ARC	Asosa University
12	4	Field visit	KOPIA	Melkassa ARC	Amhara & KOPIA office
24	3	Practical training	MoA	Melkassa ARC	Oromia, Amhara & SNNPR
25	6	Practical and theoretical training	SG2000	Negele Arsi	West Arsi
2	1	Field visit	EIAR/MARC	Melkassa ARC	Eritrea
15	3	Practical and theoretical training	MoA	Adama& MARC	Somalia region
18		Onion seed production technique training	ATA	Adama	Oromia
40	16	Tomato Field day	MARC	Lode Hetossa	Arsi zone
4	1	Tour	KOPIA	MARC	South Korea
55	10	Onion seed production techniques	MARC (AGP-II)	MARC	Oromia
517	187				

Note: KOPIA=Korea Program on International Agriculture

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Field work and data collection is under way to generate technology and information on subtropical fruit crops.

The pre-extension demonstration of subtropical fruit crops work has been done with six avocados, four mango varieties in different areas of the country. In order to demonstrate the technology, assessment work was done in advance on the preference and demand of the farmers to adopt the technology. The demand for the technologies is very high even though the capacity and the mandate of the institute is not yet in a position to supply sufficient planting materials that are being demanded by the end-users. Therefore, nursery sites and mother blocks were established in order to capacitate and continue the demonstration work of mango, avocado, in the mandate areas. A total of 110 farmers were involved in the demonstration. Due to the high demand that has been created, nurseries and mother blocks were established. Some farmers and district agricultural development office workers have started multiplying planting materials of these varieties from their own mother blocks and nurseries as well along with other neighboring farmers supported by the research centers.

Table 1. Subtropical fruit crops planting materials multiplication and distribution.

Crop	Planting materials	Amount distributed	Beneficiaries
Avocado	Grafted seedlings	6725	Private farmers, universities, farmers union, farmers associations, fruit micro enterprise, industries, private and public research, seed producing enterprise, development institutes, NGO's and MOA offices
	Scion	6100	
Mango	Grafted seedlings	5725	
	Scion	7555	

More than 2000 trainees, visitors, and advisees of fruit growers, development agents, students (elementary, high school, and university), agricultural experts, and several researchers from federal and regional research centers, university instructors were briefed about sub-tropical fruit crops production, management, and postharvest handlings. They got experiences and information on research methodologies, trial field management, nursery establishments, and handling. In addition, they are benefited by further acquainted about grafting techniques, seed production, preparation and handling, planting materials preparations, management options, and data collection techniques.

Two banana varieties Denkua-1 and Lady Finger have been released and registered by national variety releasing committee and are under process to be registered in crop variety registered book for MoA. The varieties are under multiplication at MARC for the supply of initial planting materials for further utilization by the end-users. Among nine banana genotypes (Lady Finger, Paracido Alrey, Ambowha Selle-3, Dinkua-1, Chines Dwarf, Williams Hybrid, Ambo-2, Ambo-3 and Dinkua-2) along with one standard check (William-1) that was carried out in the period of 2013 to 2018. At multi-environment banana variety trial, the tropical fruit research program has identified two banana varieties Dinkua-1 and Lady Finger which have been released and registered consecutively and are being multiplied to deliver for end users.

Table-2 Tropical fruit crops planting materials multiplication and distribution

Banana	Suckers	5733	Private farmers, universities, farmers union, farmers associations, fruit micro enterprise, industries, private and public research, seed producing enterprise, development institutes, NGO's and MOA offices
Papaya	Seedlings	10516	
	Seed	1570 gm	

Ten thousand tissue culture banana plantlets and 30,000 papaya seedlings are prepared for further distributed to private farmers, universities, farmers union, farmers associations, fruit micro enterprise, industries, private and public research, seed producing enterprise, development institutes and NGO's. MoA offices

A total of 1621 male and 424 female farmers, subject matter specialists, development agents, and students were trained on improved production of tropical fruit crops. Several researchers from federal and regional research centers, university instructors were briefed about tropical fruit crop production, management, and postharvest handlings. They also got experiences and training on research methodologies, trial field management, and nursery establishments, and handling. Basically, on tropical fruits, Seed production, preparation, handling, planting materials preparations, management, and data collection techniques.

Food Science and Nutrition Research

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Banana (Musa spp.) is an important ingredient of several dishes. It's nutritional and other biochemical composition of released and improved desert and cooking types are yet to be scientifically studied fully. In the present study, the most popularly cultivated species of cooking and desert type banana in Ethiopia selected. The objective of this study was to determine their physicochemical profiling and nutritional quality of desert and cooking banana varieties. The chemical composition and some physicochemical characteristics of the fresh fruit and flour obtained from seventeen different banana varieties are presented. A randomized complete design with three replications was used. Length, width, peel and pulp thickness, pulp to peel ratio, total soluble solids, pH, titra table acidity, ash and moisture of desert banana (Fresh) and mineral contents are the most important parameters to evaluate the quality of banana including potassium. The different varieties affected the fruit physical characteristics significantly (P≤0.05). The Cardaba varieties fruit was found to be the heaviest and the longest. The Kitawira and Nijiru varieties had the smallest, shortest and thinnest fruit. The Cardaba, Nijiru, Matoke, and Kitawira contained more pulp weight than peel weight. Most fruit chemical quality parameters were significantly (P≤0.05) affected by the varieties. The chemical composition of the flour also varied according to the variety and types of banana. Among others, the Cardaba variety was found to have high fruit weight, juice volume, total soluble solids, dry matter, and low total catestai

71.53–76.56% moisture. The sensory analysis of desert banana type was evaluated. Thus, there was no significant difference between varieties at P≤0.05 and sensorial acceptability in most varieties. The current study revealed the variations of biochemical compositions of desert and cooking banana varieties. This will be useful for the exploitation of these crops to obtain and formulate the value-added products. These varieties are recommended for different food product development by food processors in Ethiopia.

The near-infrared reflectance spectroscopy has been used to determine the ash, moisture, crude protein, iron, zinc to determine the physical and chemical properties of sorghum grain quality. Sorghum grain has approximately 65–70%, 0-4440, 0-27, of starch, tannin and amylose concentrations compared to other cereals like maize, wheat, tef. Because several genetic systems control the starch, tannin and amylose quality of cereals, it is essential to regularly monitor starch, tannin, and amylose in breeding programs for product development like injera, porridge, bread, and other products. Our objective was to examine the potential of near-infrared reflectance spectroscopy (NIRS) to enhance the efficiency of sorghum research efforts by partially replacing more expensive and time-consuming wet chemistry analysis. The determinations of tannin, starch, and amylose in sorghum have been limited by methods which are slow and relatively expensive. More than 108 sorghum samples were used to develop NIRS models for starch, tannin, and amylose. Experimental data obtained with a near-infrared reflectance (NIR) instrument. Models were determined tannin, starch, and amylose with coefficient for determination being 0.815, 0.983, 0.762) with tannin, starch and amylose respectively. Forty-six additional samples were used for validation. The coefficient of determination for validation (R(2)(v)) were 0.589 for tannin, 0.910 for total starch and 0.697 for amylose. The method is rapid (less than 1 min), relatively accurate, involves little or no sample preparation, and provides a direct readout of

tannin, starch, and amylose. The test is non-destructive and, therefore, the model can be used for any sorghum grain quality tests. Minimum sample required is approximately 3-4g and 50-100g for flour and grain samples respectively. Care in sample selection, preparation (grinding and filling the sample cell), and monitoring with a reference method is necessary for consistent meaningful results. Therefore, the NIRS models can be used to support the sorghum breeding program efforts.

The study was carried out to determine the acceptability of porridge, injera and "kita" developed from different proportions of Finger millet with ground nut, sweet potato and soy bean composite flours. Functional and proximate composition of the composite flours were characterized and sensory attributes (appearance/color, aroma, mouth-feel, taste and overall acceptability) of porridge, injera and "kita" made from the composites were evaluated using a 5-point Hedonic scale. The composite flour with highest protein content was obtained in case of 50%Finger millet: 50% Common bean flours. Porridges of acceptable quality were prepared from composite flours of Finger millet and Common beans. The study shows well accepted porridge prepared from the formulation of 87.5% finger millet and 12.5% common bean. The use of common bean in substitution of finger millet can enhance utilization of legumes and alleviate problems of protein malnutrition by avoiding relying on a single crop.

The aim of this study was to develop and characterize quality protein maize-based food products blended with orange fleshed sweet potato flour, which is rich in beta carotene for industrial use and home consumption and to increase the utilization of orange fleshed sweet potato. Quality protein maize –orange flesh sweet potato composite flour was prepared by mixing quality protein maize flour with orange

flesh sweet potato flour at six proportions (%); 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50. The proximate composition, the mineral content and the functional properties of composite flour were analyzed. Water absorption capacity values of composite flour were increased by increasing the amount orange flesh sweet potato except proportion (%); 90:10, and 80:20. The ash content of the mixed flour was increased from 1.437% to 2.937% when the amount of orange fleshed sweet potato increased whereas the content of moisture, fat and protein were decreased. The proximate composition and the sensory analysis of the porridge products were evaluated. The porridge sample had the highest ash content, carbohydrate content and energy value whereas it had the lowest moisture content, fat content, fiber content and protein content than the composite flour of quality protein maize and orange fleshed sweet potato. The overall acceptability of the sensory analysis showed that their no significant different among the treatment. The results obtained in this study showed that highly nutritious porridge can be developed from quality protein maize –orange fleshed sweet potato composite flour.

Trainings were organized for farmers, DAs and frontline experts and local leaders. A total of 404 peoples were trained on food recipes development and demonstration of sorghum (160), common beans(132) and banana and tomato (112).

Table 1. Training participants

Training	Sorghum food recipes development and demonstration			Common beans food recipes development and demonstration			Bannana and tomato food recipes development and demonstration		
	M	W	Total	M	W	Total	M	W	Total
Farmers	55	95	150	20	95	115	28	74	102
DA	4	0	4	5	2	7	3	1	4
Experts	5	1	6	7	3	10	4	2	6
Total	64	96	160	32	90	132	35	77	112

Food science and nutrition laboratory serve a lot of samples for external stakeholders and internal (MARC) customers/stakeholders. In 2019, a total of 1905 samples were processed both in grain quality characterization

and product development of sorghum (1567), common beans and wheat (148) and other crops (190).

Table 2.Total laboratory service for internal (MARC) and other customers during in 2019

Customers/stakeholders	On sorghum grain quality analysis and product developments			On common beans and wheat grain quality analysis and product developments			Product development (Injera, porrade and other products)	
	Wet chmistry	Product development	Total	Wet chmistry	Product development	Total	Product development	Total
Internal(MARC)	1300	65	1365	54	18	72	115	115
External	110	14	124	76	-	76	45	45
University (AAU,HU)	78	-	78	-	-	-	30	30
Total	1488	79	1567	130	18	148	190	190

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Natural Resources Management

Integrated Soil Fertility and Health Management Research

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Activity 1.1 Response of Maize to Blended (NPS) Fertilizers at Central Rift Valley of Ethiopia

The activity was done for three consecutive years in Dugda and AJ district on farmer field during 2017 - 2019. The experiment was laid down in split design with three replications. MH-140 and Melkassa 2 maize varieties were used as a test crop. NPS was used as basal application and Urea as a source of N which was applied in spilt.

The summery results of the data of the grain yield were significantly influenced by the effect of NPS + Urea fertilizer application. Grain yield of Melkassa-2 was most significantly increased at 200 NPS + 150Urea/ha. The increase in seed yield at this level exceeded the yield obtained at previous recommendation of NP fertilizers by about 102.5%. Similarly, for the case of NPS the highest mean grain yield was obtained from fertilizers applied at the rates of 100 kg NPS + 200 kg Urea/ha with an increment of 105.7% yield advantage over the previous recommended NP fertilizer. In addition, treatments above the minimum acceptable marginal rate of return for both blends could be recommended as alternative rate for users.

Table 1. Grain yield (kg/ha) response of MH- 140 and Melkassa 2 maize varieties to NPS blend fertilizer

Treatment	Melkassa 2	MH -140
0 + 0	2207.6	1219.7
100 NPS + 150 Urea	3493.4	4044.5
150 NPS + 150 Urea	3695.1	4674.7
200 NPS + 150 Urea	4203.2	4839.6
250 NPS + 150 Urea	4015.6	4573.9
100 NPS + 200 Urea	3593.7	5134.6
150 NPS + 200 Urea	3151.3	4660.5
200 NPS + 200 Urea	4157.0	4513.1
250 NPS + 200 Urea	4028.5	5094.6
100 NPS + 250 Urea	3036.5	4230.6
150NPS + 250 Urea	3641.0	4551.0
200NPS + 250 Urea	3986.2	4780.7
250NPS + 250 Urea	3648.1	4745.5
100 DAP + 50 Urea	2075.8	2495.4
LSD	827.24	973.8
CV%	20.41	19.86

Table 2. Partial budget analysis for the influence of NPS Blend fertilizer on Melkassa 2 maize grain yield

Treatments	PY kg/ha	APY (kg/ha	GB (Br.)	CIF	TVC (Br.)	MC	NB (Br.)	MB	MRR (%)
0 + 0	2208	1987	15895	0	0	0	15895	-	-
100 NPS + 150Urea	3493	3144	25152	3669	3669	3669	21484	5589	152.35
150 NPS + 150Urea	3695	3326	26605	4396	4396	727.4	22209	724.8	99.65
200 NPS + 150Urea	4203	3783	30263	5123	5123	727.4	25140	2931	402.93

Table 3. Partial budget analysis for the influence of NPS Blend fertilizer on MH-140 maize grain yield

Treatments	PY (kg/ha)	APY (kg/ha)	GB (Br.)	CIF	TC (Br.)	MC	NB (Br.)	MB	MRR (%)
0 + 0	1220	1097	8781	0	0	0	8781		
100 DAP + 50 Urea	2495	2245	17966	2193	2192	2192	15774	6992	318.88
100 NPS + 150Urea	4045	3640	29120	3668	3668	1475	25451	9678	655.71
150 NPS + 150Urea	4675	4207	33657	4396	4396	727	29261	3810	523.79
100 NPS + 200Urea	5135	4621	36969	4406	4406	10	32562	3301	31286.54

The activity was executed at Dugda and AJ districts on farmer field during 2017 - 2019 cropping season. The experiment was laid down in split design with three replications. Melkassa 2 and MH-140 maize varieties were used as a test crop. NPSB was used as basal application and Urea as a source of N which is applied in spilt.

Analysis of variance of the data revealed that maize yield was significantly influenced by NPSB + Urea fertilizers (Table 4).

200NPSB + 250Urea	5423	4881	39046	6599	6599	727.4	32447	2168	298.11

Effect of Phosphorus fertilizer on yield and yield component of Haricot bean varieties across soil and agro-ecologies

The activity was executed at Boset (Bofa), Shalla and AJ district on farmer field during 2017-2019 main cropping seasons. The experiment was laid down out in RCBD design and factorial combination. The three varieties is used (SER119, Awash-2, and Dume) as test crops. The source of P is TSP fertilizer.

Over years pooled mean data analysis revealed that application of different levels of P fertilizer significantly influenced bean grain yield ($p<0.05$) only at Shala, while no significant effect was observed for the case of AJ and Bofa sites. At Shala, maximum bean yield was recorded from P application at the rate of 40 kg P /ha that was not found to be significantly different from all other P levels except control. Generally, the study on common bean showed only marginal differences in grain yield among different P levels in both varieties. However, based on agronomic response and partial budget analysis, P fertilizer application at the rate of 10 kg P /ha can be suggested for the production of common bean in the study areas.

Table 7. Main effects of P on common bean grain yield across location and over years Shala during 2017-2019

Treatments	Sites			
Adamitulu	A/Tulu	Bofa	Shalla	Mean
Var	Bean Yield) kg/ha)			
Dume	3012.70	2695.90	1696.50	2465.40
SER-119	2974.10	3049.50	2087.10	2703.60
Awash-2	2477.30	2545.40	1747.70	2256.80
LSD (005)	224.59	275.16	198.12	178.80
P rate (kg/ha)				
0	2767.10	2507.70	1552.10	2275.60
10	**2899.70**	**2806.40**	**1928.10**	**2544.80**
20	2622.80	2844.90	1756.50	2408.00
30	2878.80	2810.60	1976.70	2555.40
40	2938.06	2848.50	**2065.40**	2597.50
CV (%)	19.0.6	23.84	25.78	30.12
LSD (005)	NS	NS	255.80	230.80
Var * P	NS			

Table 8 Financial analysis

P rate	Total cost	Marginal cost	Net benefit	Marginal	MRR

(kg/ha)	(ETB)		(ETB)	benefit	(%)
0	0	0	24576.50	-	
10	789.25	789.25	26694.60	2118.11	268.37
20	1578.5	789.25	24427.90D	-2266.70	-
30	2367.75	789.25	25230.60D	802.67	-
40	3157.00	789.25	24896.00D	-334.57	-

The experiment has been done for two consecutive years on farmer's field at Bofa and AJ. The analyses of variance showed that application of recommended DAP has resulted in the highest grain yield of Haricot bean followed by negative control (no application of fertilizer). Hence, Grain yield was not significantly influenced by the application of rhizobial strains (HB-A15 and HB-429).

Analysis of variance of the data showed statistically significant difference ($P \leq 0.05$) due to main effect of nutrient sources and land preparation methods and their interactions (Table 2). The interaction effect of fertilizers and land preparation technique increased ($P<0.01$) grain yield of sorghum significantly. Even though, variable combination of different level and type of fertilizers with land preparation methods differed significantly in sorghum grain yield, better grain yield was recorded at the combined 0 levels of the two treatments. This might be associated with medium to high level of available nutrient in the plots/ soil. In general, grain yield of sorghum increased inconsistently with increasing application rates of nutrient sources and land preparation technique.

Table 4. Interaction effects of moisture conservation and soil fertility improvement on sorghum grain yield at Mieso in 2018.

Fertilizers	Moisture conservation	
	Tie ridging	Farmer practice
Recommended NP	1938.9[ab]	1344.9[bcd]
Farmyard manure	2334.9[a]	2165.9[ab]
Green manuring	1983.3[ab]	629.8[d]
Compost	2293.9[a]	1628.3[abc]
50% treatment 1 + 50%treatment 2	2410.0[a]	870.5[cd]
50% treatment 1 + 50%treatment 3	1833.1[ab]	1901.3[ab]
The control treatment	2206.9[a]	2258.1[a]
LSD 0.05		840.85
CV (%)		25.09

Tomato is the most grown vegetable crop with high potential to contribute for poverty reduction via increased income and food security. Its production in Ethiopia has rapidly expanded into large-scale cultivation during the past decade. Yet, average yield of tomato in Ethiopia remained low as compared to the world average. Low inherent soil fertility and its depletion are among the contributing factors. Hence, this study was designed to evaluate a combination of recommended NPS fertilizer and Tradecorp AZ Bentley plus fertilizer on tomato yield at different locations of East Shewa Zone under irrigation. The result obtained from the three locations over two years indicated that application of Tradecorp AZ Bentley plus fertilizer as supplemented to recommended mineral fertilizers improved tomato yields by 15.9 % (11.3 ton) and 4.8 % (3.0 ton) compared to recommended NPS fertilizers applied alone at Melkassa and Meki sites, respectively. The partial budget analysis results also showed higher net benefit and MRR due to application of Tradecorp AZ Bentley plus as supplementary fertilizer in combination with the recommended NPS from mineral fertilizer at Melkassa and Meki. Hence, the product can be suggested for tomato producing farmers in Melkassa and Meki area.

The study on French bean showed only marginal differences in pod yield among different bio-gold treatments during the first season of its application. However, the residual effect was able to depict pod yield differences. Besides, sole biogold application or its combined application with the recommended inorganic fertilizer improved the shelf life of French bean pods under cold storage conditions. The profitability of using biogold to produce French bean production was ranked second to full recommended inorganic fertilizer application. In addition, application of full rate of biogold in combination with half of the recommended inorganic fertilizer increased in yield advantage of about 1.3 ton over control.

Based on agronomic response and partial budget analysis, application of full rate of biogold in combination with half of the recommended inorganic fertilizer can be suggested as a supplemental fertilizer for production of French bean in the study areas.

The experiment has carried out in 2018 and 2019 off-cropping season on tomato at three locations.
The experiment was laid down in factorial arrangement of RCBD design with three replications. The variety to be used in the trial was 'Gelilea hybrid' for tomato crop. Three level of the product (600, 900 and 1200 kg/ha) and three rates of N/P (64/20, 128/40 and 192/60 kg/ ha) were used as a treatment. The new product was applied at planting whereas, NPS is used as basal application and Urea as a source of N which is applied in twice spilt. Currently, the trials were

completed and data filling in to the computer and compiling are underway.

The experiment has carried out in 2018 and 2019 off-cropping season on onion at three locations. The treatments used for trial was: Negative control, RCF, RCF + Potassium humate, Half RCF + Potassium humate and Potassium humate alone. The experiment was arranged in randomized complete block design (RCBD) in three replications. The source of N and P was NPS and Urea respectively. Preparation of working solution was 0.4 liters of potassium humate diluted in 300 liters of water and treated with the resulting solution of 1 ha. The product was sprayed in the evening or in the morning hours during the growing season starting in the phase of the appearance of 2-3 leaves every 10-15 days. All NPS fertilizer was applied as basal application at planting and the N in urea was applied in split form. The recommended seed rate Nasik Red var. was used and planting has done manually. Currently, the trials were completed and major data including soil samples yield and yield related data were collected in both three sites and, data compiling and data filling into computers are underway.

Two earthworm species (a local collection and *Eisenia fetida*) are under multiplication for research purpose and distribution to farmers in Adama and Lume districts. About 12,900.00 (>3 kg) of worms of the locally collected species and over 186,000.00 (>46 kg) of E. *fetida* were multiplied.

Training on integrated soil fertility management (organic and inorganic) was given for 20 farmers at Adulala and 22 farmers at Jogo gudedo watersheds. Development agents (3) from Adulala and 3 from Jogo Gudedo participated on the training.

Junior researchers were also given training on data management analysis software. Experience on soil fertility management was also shared to researchers from Welkite research center. 120 plant science students from Welkite university were share an experience on soil sample preparation and soil sample collection methods. List publications published during the reporting period.

Dejene Abera, Kibebe Kibret, Sheleme Beyene 2018. Tempo-spatial landuse/cover change in Zeway, Ketar and Bulbula sub-basins, Central Rift Valley of Ethiopia. Lakes &Reserv; 1–17. DOI: 10.1111/lre.12240

Dejene Abera, Kibebew Kibret, Sheleme Beyene, Fassil Kebede. 2018. Nitrate, Leaching under farmers' Fertilizer and Irrigation Water Use in the Central Rift Valley of Ethiopia. International Journal of Plant and Soil Science,21(6). DOI: 10.9734/IJPSS/2018/39076.

Dejene Abera, Kibebew Kibret, Sheleme Beyene, Fassil Kebede. 2018. Spatial and Temporal Dynamics of Irrigation Water Quality in Zeway, Ketar, and Bulbula sub-Watersheds, Central Rift Valley of Ethiopia Ethiop. J. Agric. Sci.28(3) 55-77.

Tesfaye Balemi, Dejene Abera, Yifru Abera (eds). 2018. Proceedings of TAMASA (Taking Maize Agronomy to Scale inAfrica) Project. Science Week Meeting, 28-29 August, 2018. Addis Ababa, Ethiopia.

Dejene Abera, Agere Lupi, Getinet Adugna, Mesfin Hundesa, Israel Bekele, Kiya Aboye, Jibril Mohammed, Fitih Ademe. 2019.Soil Fertility Management Research: Major Achievements, Challenges and Future Prospects. *In* GashawbezaAyalew (ed.) proceedings of 50thAnnivarsary of Melkassa Agricultural Research Center. 27–31 August 2019. 49-372.Melkassa Agricultural research Center, Melkassa.

Zi-Qiang Yuan, Rong Zhang, Bin-Xian Wang, Ben-Qiang Gao, Getachew Ayana, DejeneAbera, Muhammad Ashraf, Feng-Min Li, 2019. Film mulch with irrigation and rainfed cultivations improves maize production and water use efficiency in Ethiopia. Ann Appl Biol. 175:215–227.

Integrated Watershed Management

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The activity was initiated to assess the status of implemented structures in relation to the identified technical standards and testing how the local people recognize the structures. Hence, the study showed that most of the implemented soil and water conservation structures in the study area are under the scientifically determined standards and some of them are above the technically recommended standards. In areas where the structures are above the standard, it leads to loss of productive land and those under the specified standards leads to distraction of structures and damages to downstream areas. Due to this runoff generated over tops causing rill and gully erosion which is difficult to control. In addition to these, major constraints in the study area with respect to soil and water conservation practices is lack of training, skilled manpower, centralized planning, weak extension services and lack of farm tools. Accordingly, every year those soil and water conservation practices implemented by community mobilization are not standardized and thus it is difficult to manage the watershed in different areas.

Trainings were organized for farmers, agricultural experts and DAs. A total of 139 peoples were trained on physical soil and water conservation (115) and biological soil and water conservation (24).

Table 1: Training participants

Title of training	Participants	
	Male	Female
Physical soil and water conservation	53	12
Biological soil and water conservation	62	12
Toltal	115	24
Grand total	139	

Advisory service has delivered for two MSc students from the department of soil and water conservation of Debere Birhan University and one student from Hawassa University.

Bekele, D., Alamirew, T., Kebede, A., Zeleke, G., Melese, A.M., 2019. Land use and land cover dynamics in the Keleta watershed, Awash River basin, Ethiopia, Environmental Hazards18: (9246–265)

Bekele, D., Alamirew, T., Kebede, A., Zeleke, G., Melese, A.M., 2019. Modeling Climate Change Impact on the Hydrology of Keleta Watershed in the Awash River Basin, Ethiopia. Environmental Modeling & Assessment 24:95–107

Abebe Bezu, and Keteme Tezera, K. (2019). Impacts of soil and water conservation on crop yield, soil properties, water resources, and carbon sequestration: A review. Journal of Soil Science and Environmental Management, 10(5), 103-113.

Irrigation and Water Harvesting Research

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The field experiment was carried out at Melkassa Agricultural Research Center, Ethiopia during the wet growing season of 2017, 2018 and 2019, under lysimeter. The aim of this study was to estimate the seasonal water demand and crop coefficient of Maize *(Melkassa II)* for effective irrigation water planning and management. Crop coefficient (Kc) determined for each growth stages as the ratio of Etc to ETo. ETc determined by soil water balance equation and ETo computed by CROPWAT version 8.0 using the FAO Penman-Monteith equation. The seasonal ETc was found to be calculated for initial, development, mid-season, and late-season stages, respectively. The measured crop coefficient (Kc) values were also calibrated for those stages, respectively. Some of the Kc values found in this experiment differed slightly from the average of FAO estimation. This indicates that there is a need to develop Kc values for given local climate conditions and cultivars. The first- and second-year data were summarized and presented in Table 1. The third-year data were collected and analysis underway. Thus, all the three years data compiled results should be summarized and presented for complete document

Table 1: Crop water requirement and crop coefficient of maize under lysimeters

Growth Stages	Year-I		Year –II		Average	
	CWR	Kc	CWR	Kc	CWR	Kc
Initial	3.06	0.67	3.73	0.67	3.40	0.67
Dev't	4.07	0.97	4.70	0.99	4.39	0.98
Mid	5.52	1.21	6.25	1.25	5.88	1.23
Late	3.50	0.63	3.82	0.62	3.66	0.63

(Sorghum bicolor .)

The field experiment was carried out at Melkassa Agricultural Research Center, Ethiopia during the wet growing season of 2017, 2018 and 2019, under lysimeter. The aim of this study was to estimate the seasonal water demand and crop coefficient of Sorghum *(Teshale)* for effective irrigation water planning and management. Crop coefficient (Kc) determined for each growth stages as the ratio of ETc to ETo. ETc determined by soil water balance equation and ETo computed by CROPWAT version 8.0 using the FAO Penman-Monteith equation. The seasonal ETc was found to be calculated for initial, development, mid-season, and late-season stages, respectively. The measured crop coefficient (Kc) values were also calibrated for those stages, respectively. Some of the Kc values found in this experiment differed slightly from the average of FAO estimation. This indicates that there is a need to develop Kc values for given local climate conditions and cultivars. The first- and second-year data were summarized and presented in Table 2. The third-year data were collected and analysis underway. Thus, all the three years data compiled results should be summarized and presented for complete document.

Table 2. Crop water requirement and crop coefficient of Sorghum *(Teshale)* under lysimeters

Growth	Year-I		Year –II		Average	
Stages	CWR	Kc	CWR	Kc	CWR	Kc
Initial	2.33	0.41	2.51	0.45	2.42	0.43
Dev't	4.57	0.96	3.99	0.84	4.28	0.90
Mid	5.91	1.17	5.65	1.13	5.78	1.15
Late	3.73	0.56	4.07	0.66	3.90	0.61

Plant Biotechnology Research

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1. In 2019 cropping season, 6708 Banana seedlings of six varieties were distributed for different stakeholders including Fantale, around Melkassa/Bishola, Arbaminch, Chiro, Adama, Sinana ARC, Arsi surroundings and Sire district. Additionally, Melkassa PTC laboratory currently propagating these varieties and about 20,000 plantlets were on multiplication stages.
2. The Melkassa Plant Biotechnology Tissue Culture laboratory generated a full micro propagation protocols for six Banana varieties (namely: Poyo, Gaint Cavendish, Dwarf, Butuza, Grande naine and Williams 1), 5 Sugarcane cultivars brought by Ethiopian Sugar Corporation, Aloe Vera (Linn.) and disease cleaning and multiplication protocol for Elite Garlic Varieties. Using the generated protocols, the program has been propagating Banana as medium commercial laboratory.
3. Now, the program have been engaged on nine activities under three Project titles: five activities on project "Development and Application of *in vitro* Techniques for Mass Propagation, Haploid Induction and Conservation of Selected Plants" namely '*In Vitro* Protocol Development/Optimization for Production and Mass Propagation of Disease Free Materials of Elite Citrus Varieties', 'In vitro protocol development/optimization, mass propagation of disease free materials and short term conservation of elite Date palm varieties', '*In vitro* protocol development/optimization for elite cooking banana varieties', '*In vitro* multiplication/scaling up of tissue culture banana using the already developed protocol for three Cavendish cultivars Dwarf, Giant and Poyo' and 'In Vitro Conservation of Banana Germplasm through a Slow Growth Technique' and under project title "Application of Molecular techniques for crop improvement" two activities entitled:'Genetic diversity study in pepper (Capsicum annum L.) germplasm using SSR markers' and

'Morphological and Molecular Characterization of Banana genotypes.', and the last not the least project "Bio-organic agriculture" which includes two activities; Characterization of biofungicidal activity of avocado rhizibacteria against *Phytophthora cinnamomi* and Characterization of *Phytophthora cinnamomi* Rands from Avocado (*Persea americana*) Nurseries and Orchards.

4. Lots of organizations including from University students, research centers and investors got insight and visited the technologies delivered by tissue culture laboratory. Ten students from different universities come to the laboratory for apparent ship for a month to three-month time.
5. Training was provided to laboratory technicians from centers plant TC and pathology department on laboratory safety and cotton genetic engineering, and we had also participated on plant tissue culture manual preparation forum at NABRC at Holeta.
6. One thousand five hundred Aloe vera seedlings were propagated for Wendogenet ARC

Plant Protection Research

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1. The inhibitory effect of selected fungicides on the growth of hot pepper *Fusarium oxysporum* was evaluated under *in vitro* condition. The *in vitro* mycelial growth inhibition of five fungicides at recommended dose was added to un molten PDA just before pouring it into plates and the virulent FOC isolate 4DGK, isolated from infected hot pepper fields in Dugda district and identified as the most aggressive isolates was evaluated in a dual culture assay. Statistical analysis revealed that, URGI 75% WP, Twinstar 75 WG and Nativo SC 300 was best performing in inhibiting mycelial growth of test organism among *in vitro* evaluation. Three fungicides having the nature of both systemic and contact action strongly inhibited the growth of the test fungi. URGI 75% WP (Carbendazim + Mancozeb; 120 + 640 g/Kg), Nativo SC 300 (Trifloxystrobin + Tebuconazole; 100:200g/l), Twinstar 75 WG (Trifloxystrobin + Tebuconazole; 50:25 % w/w) led to 98.8, 94.0 and 92.3% inhibition of mycelia, respectively. This finding might be good news for Ethiopian hot pepper producers.
2. The percentage wilt incidence varies among treatments were observed on experiment conducted on integrated approach to manage fusarium wilt of hot pepper. The highest wilt incidence of fusarium wilt was recorded on the plot treated by animal manure, control and Agro Laxyl with the wilt percentage of 72, 70 and 68% respectively. Relatively the wilt incidence was lower in the plot treated with CaCo3 + Animal manure (40%) and Animal Manure + Biochar (40%).
3. Thirty-one papaya lines were evaluated for their reaction to black spot disease under green house. Only MK-120 L#94 exhibited moderate resistance. This line can be

further evaluated in the field condition and inter in to production system. The overall incidence among lines was 100% which shows none of the 31 lines were free of the pathogen. Now a day this pathogen is emerging significantly in the central Rift valley of Ethiopia.

- Forty-five students from Bule Hora, 42 students from Selala and 50 students from Semara Universities, were shared an experience from Plant protection division of the Plant Pathology and Agricultural Entomology programs. In Addition, 3 Lecturers from Welkite, 2 lecturers from Dilla and 4 Lecturers from Dambi Dollo universities were also shared the experience and capacitated in the subject matter. Development agents and farmers located in Central Rift valley were trained on major diseases and insect pest of economically important crops and their management options.

1. One Plant Pathology Greenhouse were rehabilitated by facilitating the condition in international standard requirements and made ready for an experiment which requires controlled condition.
2. Refrigerator having high cooling capacity were bought and installed in plant Pathology Laboratory.

1. Molasses trap, pheromone trap and check without lure were evaluated for FAW trapping efficacy on both maize and sorghum crops. Maximum number of FAW recr d

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was recommended at the rate of 1250ml/ha for the farmers to protect fall armyworm damage from maize plants.

3. Dursuban 48% EC, Chlorpyrifos chemical insecticide was verified against fall armyworm damage on maize crops at Melkassa. The current study showed that, significant protection was observed to maize from fall armyworm damage by using chloropyrifos chemical and equivalent results were observed with the standard check (Tracer-480SC) and (Dursuban 48% EC, Chlorpyrifos) at the rate of 1Lt/ha). Therefore, Chlorpyrifos was recommended at the rate of 1000ml/ha for the farmers to protect fall armyworm damage from maize plants.

1. Yield loss assessment of Cowpea due to Aphids was studied from 2017 to 2019 at Mieso during main season. The experiment consisted insecticide treatment, Dimethoate 400g/l sprayed at 3, 6, 9, 12 and a combination of 3+6+9+12, weeks after crop emergence. Cowpea varieties Bole and White wonder were used for the experiment. The three-year results revealed that Diemethoate 400g/l sprayed at 3 weeks and a combination of 3+6+9+12 weeks after crop emergence resulted lower yield losses due to aphid on Cowpea varieties tested.

1. Three registered insecticides namely, Avaunt 150 SC (indoxacarb), Belt SC 480 (flubendiamide), and Tracer 480 SC (spinosad)selected based on their efficacy to control *Tutaabsoluta* were applied in different rotation sequence to determine effective rotation sequence. Plots treated with the rotation of these insecticides in sequence of Belt SC 480 followed by Avaunt 150 SC and Tracer 480 SC suffered less from *T. absoluta* damage.
2. A study conducted to determine effective rotation sequence of insecticides selected based on their efficacy for the control of onion thrips (i.e Radiant 120 SC, Fighter

and Curador) showed that the rotation of these insecticides in the sequence Fighter followed by Radiant 120 SC and Curador effectively reduced the infestation and damage of onion thrips on onion.

3. The effect of trap position and direction on capture size of *T. absoluta* adults on tomato fields was determined. Traps positioned at crop surface trapped significantly higher number of moths. Similarly, traps placed in the East direction trapped higher number of *T. absoluta* adults.
4. The integrated effect of host plant resistance and insecticides on whiteflies and their damage on tomato was determined. The results showed no significant differences between those plots treated with insecticide and non-treated plots in reducing the infestation from white flies

- Critical period of weed competition for mung bean ranges between 21 and 35 days after crop emergence. This indicates that, mung bean tolerates weed competition up to 21 days after crop emergence and weed management before this date is not economical. On the other side mung bean cannot tolerate weed competition between 21 and 35 days after crop emergence. Weed management practices before and after this period has no significant yield increment. Similarly, twenty-seven major weed species were identified as potential and dominant weed flora in the experimental field.
- Effects of Weed Control Practices on yield and yield contributing parameters of mung bean varied significantly due to different weed control practices. Analysis of variance showed that a significant difference in pod per plant, seed per pod, hundred seed weight and grain yield were observed among year, location and different weed control practices. Similarly, significant difference exists in weed dry matter and weed densities across locations in 2018 and 2019. The highest grain yield was obtained from weed free plot and followed by combination of s-metolachlor plus hand weeding and twice hand weeding at 7 and 21 days after crop emergence. This indicates that s-metolachlor with supplementary hand weeding and twice hand weeding are the best alternative options of weed control in mung bean.

Technology Multiplication and Seed Research

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Effect of different threshing methods /Tractor treading, beating by stick, multi crop thresher and cattle treading/ on some common bean cultivars like Awash-1, Awash-2 and Nasir were tested for seed quality. We found that stick beating is higher seed purity than tractor treading and multi crop thresher but the purity difference was not significant ($P<0.05$). However, stick beating, multi crop thresher and tractor treading showed significantly ($P<0.05$) higher purity than cattle treading. Threshing of stick beating by man power resulted higher germination percent and physical purity than other three threshing methods irrespective of the varieties. Variety*threshing" interaction there was indication that one or more of the varieties' responded to the different normal seedlings in all threshing methods. Awash-1, Awash-2 and Nasir threshed similarly through four threshing methods. Nasir showed loss of germination percentage (5.33%) when threshed by multi crop thresher and looks to have caused the significant interaction effect (Fig 1). Results suggest that Nasir may require other threshing methods to maximize the percentage of normal seedlings or multi crop thresher need adjustment. Generally, different threshing methods produces breaks, cracks, damages and scratches in seeds which in turn results in abnormal seedlings and dead seeds of questionable planting value.

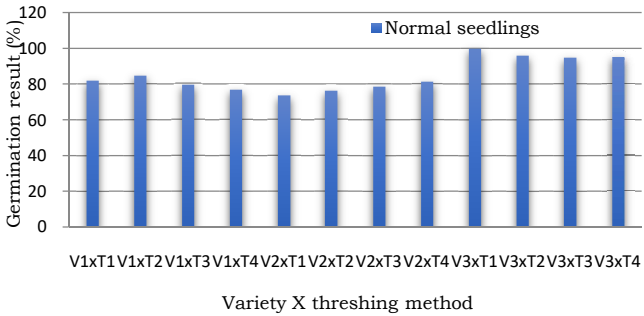

Fig 1. "Variety by Thresher" interaction effect

Total yields of early generation seed (EGS) crops varieties multiplied in 2019 main season was1215.11 quintals from which 346.02 quintals were pre-basic whereas 863.09 quintals were basic seeds. EGS yields of five maize seed varieties multiplied at MARC were 578.30 quintals from which 130.30 quintals pre- basic and 448 quintals basic seeds. Common bean seed yields of six varieties multiplied were 586.60 quintals from which 193.60 quintals pre- basic and 393 quintals basic seeds. Among warm season vegetable seed yields one onion variety was 4.5 quintals pre-basic whereas yields of four tomatoes seed varieties were 0.107 quintal pre-basic and yield of one pepper seed variety was 0.105 quintal pre-basic seeds (Table 1). Laboratory results indicated that all crops varieties multiplied in 2019 cropping season was fulfilled the national seed quality standards and certified to distribute for different stake holders.

Table 1. Accomplishment of main season 2019 EGSM by crops, varieties and seed classes,

Crop	Variety	Seed class	Planned	Accomplished	Percentage of Acc.
	Melkassa-2	PB	25	28	>100
	Melkassa-2	B	250	294	>100
	Melkassa-6Q	PB	25	12	48
Maize	Melekassa-6Q	Basic	150	154	>100
	Melkassa- 4	PB	75	28.3	37.73
	Melkasaa -1	PB	25	52	>100
	Melkassa-3	PB	25	10	40.00
Sub-total			575	578.30	100.57
Common	Awash-1	PB	56	26.10	46.61
beans	Awash-2	PB	99.52	89	89.43
	Awash-2	Basic	155.20	143	92.14
	Nasir	PB	48	61.70	>100
	Nasir	Basic	226.4	250	>100
	SER-125	PB	16	10	62.50
	SER 119	PB	8	6.80	85.00
Sub-total			609.12	586.6	96.30
Mung bean	N-26	PB	16	16	100.00
Teff	Boset	Basic	32	28	87.50
Sorghum	Melkam	PB	5	3	60
	Dekeba	PB	5	3	60
Tomatoes	Fetan, Gelilema, Chali and tomato ARTd2	PB	0.25	0.107	42.80
Pepper	Melka Awaze	PB	0.25	0.105	42.00
Total			1242.62	1215.11	97.77

*EGSM = Early generation seed multiplication; Note: M-2= Melkassa-2, M-4, Melkassa-4

Total yields of early generation seeds multiplied in 2019 off season were 64.65 quintals which all are pre basic. Among total EGS produced 6.5 quintals were two maize lines whereas 57 quintals were four common bean varieties. Warm season vegetable seeds multiplied in this cropping season were onions & pepper crops varieties which are 1.15 quintals (Table 2).

Table 2. Accomplishment of off season 2019 EGSM by crops, varieties and seed classes

Crops	Varieties/ Lines	Seed class	Planned	Accomplished	Percentage of Acc.
Maize	CML-144	PB	5	5.5	>100
	CML-159	PB	2	1	50.00
Sub-total			7	6.5	92.86
Common beans	A-2	PB	16	21.60	135.00
	Nasir	Pre basic	16	16	100.00
	A-1	PB	8	9.50	118.75
	SER 119	PB	8	9.90	123.75
Sub-total			48	57	118.75
Onion	Nafis	PB	1.25	0.15	12.00
	Nasik	PB	1	0.10	10.00
Pepper	Marako Fana	PB	1.20	0.80	66.67
	Melka Awaze	PB	0.125	0.10	80.00
Sub-total			3.58	1.15	32.12
Total			58.58	64.65	110.36

Multiplied EGS were distributed to different stakeholders after certified by regulatory body. All seed quality components were analyzed according to national seed quality standards. Among the total seeds produced in 2011 E.C. cropping season 1164.11 quintals were distributed to different stakeholders whereas 51 quintals of maize and common bean seed varieties were carried over (Table 3). The distributions of EGS produced in 2019. off season were not yet started due to shortage of cleaning machine.

Table 3. Main season early generation seed distribution plan & accomplishment (quintal)

Crop	Variety	Seed class	Planned	Distributed	Left over	% of distribution	Stakeholder
Maize	Melkassa-2	PB	28	28	0	100	OSE, ASE, SSE, Bora D. & Oda
	Melkassa-2	Basic	294	263	31	89.46	B. Unions
	Melkassa -6Q	PB	12	12	0	100	OSE, Sinana ARC, Hawassa
	Melkassa-6Q	Basic	154	154	0	100	CA,
	Melkassa- 4	PB	28.3	28.3	0	100	OSE, Oda bultum U.,
	Melkassa-1	PB	52	52	0	100	Haramaya U., Afar Region PO.,
	Melkassa-3	PB	10	10	0	100	Lega hida district Agri. Office, Hawassa CA,
Common beans	Awash-1	PB	26.10	26.10	0	100	OSE, Bora D. & Oda B Unions,
	Awash2	PB	89	89	0	100	OSE, Adama Agri. Office, Oda
	A-2	Basic	143	143	0	100	B. Unions
	Nasir	PB	61.70	61.70	0	100	Adama Agri. Office, Oda B.
	Nasir	Basic	250	230	20	92	Unions, OSE, ASE, Bahir dar U., ECC, OSE,
	SER 125	PB	10	10	0	100	TTC, East Wollega Agri. office,
	SER 119	PB	6.80	6.80	0	100	TTC,
Mung bean	N-26	PB	16	16	0	100	Sorghum R.P, Wirtu Bosat Union,
Teff	Bosat	Basic	28	28	0	100	Adama Agri. office, wake Tiyo Farmers, Upper awash farmers, Boset Agri., Dodata Agri. office
Sorghum	Melkam	PB	3	3	0	100	Chiro ARC
	Dekab	PB	3	3	0	100	
Tomatoes	Fetan, Gelalema, Chali and tomato ARTd2	PB	0.107	0.107	0	100	Dilla & Woliyat Usni student, Wellaga U., Lume, Bosat,
Pepper	Melka awaze	PB	0.105	0.105	0	100	Adama Agri. offices,

*ECC= Ethiopia catholic church

Annex 1.Human Resources at MARC, Research staff

Programs/Processes	PhD	MSc	BSc	Diploma	Others	Sum
Crop	8	34	16	11	43	112
Natural Resource Management	3	12	9	2	11	37
Agricultural Mechanization	0	11	10	7	6	34
Climate Change & Geospatial	0	2	2	0	0	4
Agricultural Economics	1	4	1	0	0	6
Extension & communication	1	3	3	1	2	10
Plant Protection	3	9	1	0	10	23
Sericulture	1	4	2	1	8	16
Food Science	1	1	9	1	1	13
Biotechnology	1	3	1	0	0	5
Technology Multiplication	0	1	2	1	17	21
Sum	**19**	**84**	**56**	**24**	**98**	**281**

Annex 2. Human Resources at MARC, administrative and support staff

Program/Processes	BSc		Diploma		Others		
	M	F	M	F	M	F	Sum
Human Resource	1	2	0	2	1	1	7
Procurement and Finance	6	8	0	2	0		16
Information Communication	1	0	2	2	0	1	6
Property Management	4	0	3	0	63	17	87
Internal Audit	0	0	0	1	0	0	1
Ethics	1	0	0		0	0	0
Secretary	0	0	0	2	0	0	2
Transport	2	0	5		18	1	19
Sum	**15**	**10**	**10**	**9**	**82**	**20**	**146**