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Preface

We would like to present, with great pleasure, the inaugural volume-7, Issue-5, May 2021, of a scholarly journal, *International Journal of Environmental & Agriculture Research*. This journal is part of the AD Publications series *in the field of Environmental & Agriculture Research Development,* and is devoted to the gamut of Environmental & Agriculture issues, from theoretical aspects to application-dependent studies and the validation of emerging technologies.

This journal was envisioned and founded to represent the growing needs of Environmental & Agriculture as an emerging and increasingly vital field, now widely recognized as an integral part of scientific and technical investigations. Its mission is to become a voice of the Environmental & Agriculture community, addressing researchers and practitioners in below areas.

Environmental Research:

Environmental science and regulation, Ecotoxicology, Environmental health issues, Atmosphere and climate, Terrestric ecosystems, Aquatic ecosystems, Energy and environment, Marine research, Biodiversity, Pharmaceuticals in the environment, Genetically modified organisms, Biotechnology, Risk assessment, Environment society, Agricultural engineering, Animal science, Agronomy, including plant science, theoretical production ecology, horticulture, plant, breeding, plant fertilization, soil science and all field related to Environmental Research.

Agriculture Research:

Agriculture, Biological engineering, including genetic engineering, microbiology, Environmental impacts of agriculture, forestry, Food science, Husbandry, Irrigation and water management, Land use, Waste management and all fields related to Agriculture.

Each article in this issue provides an example of a concrete industrial application or a case study of the presented methodology to amplify the impact of the contribution. We are very thankful to everybody within that community who supported the idea of creating a new Research with *IJOEAR*. We are certain that this issue will be followed by many others, reporting new developments in the Environment and Agriculture Research Science field. This issue would not have been possible without the great support of the Reviewer, Editorial Board members and also with our Advisory Board Members, and we would like to express our sincere thanks to all of them. We would also like to express our gratitude to the editorial staff of AD Publications, who supported us at every stage of the project. It is our hope that this fine collection of articles will be a valuable resource for *IJOEAR* readers and will stimulate further research into the vibrant area of Environmental & Agriculture Research.

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Groundnut Cultivation: A Novel Approach using Organic Input

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Abstract— *The groundnut or peanut is one of the important legume crops of our world, produced over an area of 5.4 million ha and production of 5.43 million tones with a productivity 910 kg/ha. High profitability along with sustainability can be attained in groundnut with proper fertility management and by organic farm practices. In the recent years organic farming has gained significant importance by supporting sustainable crop production and due to its eco-friendly benefits. Organic farming system in groundnut emphasis the use of vermi-compost, FYM along with other organic amendments like bio-fertilizers, bio-pesticides etc. and hence paving way for production of organic and healthy peanuts.*

Keywords— bio-fertilizers, organic peanuts, bio control-agents, disease management.

Papers Highlights:

- *Significance of cultivation of groundnut using organic inputs.*
- *Role of bio-fertilizers in groundnut cultivation.*
- *Use of organic manures in producing healthy peanuts.*
- *Pest and disease management in groundnut using bio-control agents.*

I. INTRODUCTION

The groundnut or peanut (*Arachis hypogea*) is one of the most important legume crop of tropical and sub-tropical countries belonging to the family legume. It acts as a rich source of protein constituting 22-30% and 44 to 56% edible oil (Savage J *et al*. 1994). It is mainly used for oil extraction but due to presence of high content of protein (22 %), carbohydrates (10 %), minerals (3%), niacin (17 mg/100g) and vitamin B, groundnut possess high food value and hence consumed directly (Rajagopal *et al*. 2000). Because of its significance, a shift in cultivation practices of groundnut from conventional methods to organic methods is going to pave way for a bigger change. It helps in ensuring production of high quality seeds with increased protein and oil content.

FIGURE 1: Ground nut (*Arachhis hypongea)* plant.

Organic farming is a type of farming system where the use of synthetic fertilizers, growth regulators, pesticides and livestock feed additives is completely or partially avoided. The concept of organic farming is based on the principle of environmental, social and economic sustainability (S.K.Yadav *et al*.2013). Significant characteristics include protection of long-term fertility of soils by balancing amount of organic matter in the soil, maintaining biological life in the soil, careful use of farm equipments, ensuring nitrogen availability through the use of legumes and biological nitrogen fixation, recycling of organic materials including crop residues and livestock wastes and weed, disease and pest control using crop rotations, natural predators, diversity, organic manuring, and resistant varieties (S.K.Yadav.*et al*.2013).

Organic production of groundnut depend entirely on farm management techniques that helps in maintaining the soil fertility by ensuring optimised microbial activity (Jagdish Reddy.2019).This include incorporation of FYM or vermicompost into soil, crop rotation, use of cover crops, cultivation of green manure crops and using organically accepted fertilizers and pesticides that flourish the soil with nutrients and protect plants from pest and diseases (Jagdish Reddy.2019). Within some years, use of organic manures in groundnut production is going to be an inevitable process since it improves the physical, biological and chemical properties of soil along with increased water holding capacity and rise in crop productivity.

Organic manure supplied to the soil during production of groundnut mainly includes green manure, neem cake, enriched compost and vermicompost. This ensures the health of plant and hence the crop yield. Seed treatment in organic farming is done using bio-fertilizers and bio-pesticides such as Rhizobium, PSB, and Trichoderma Harzianum

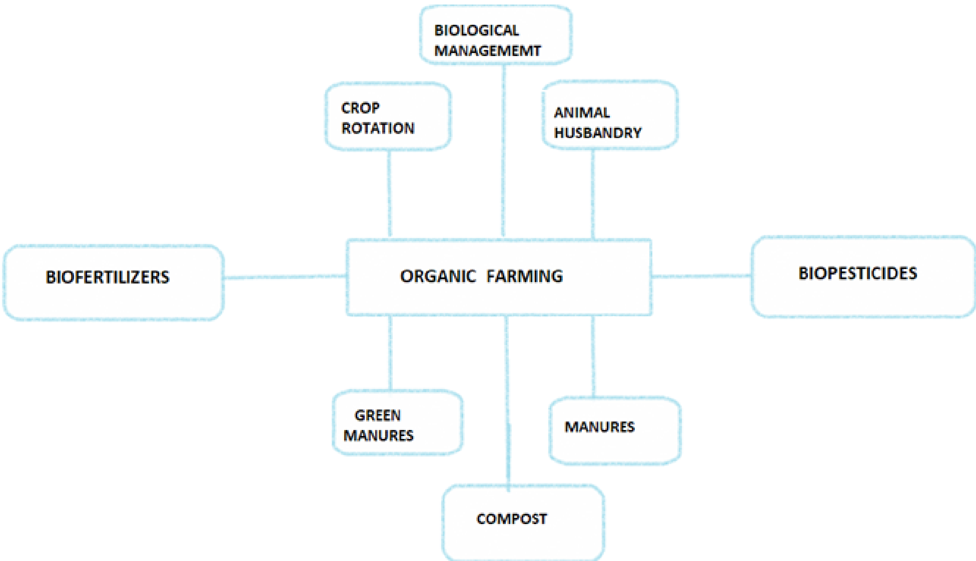

FIGURE 2: Organic Farming

II. WHY ORGANIC PEANUTS ARE RECOMMENDED?

Organic peanuts are rich source of vitamins and minerals .They are important source of manganese. It supplies phosphorous, magnesuim, vitamin E and niacin (Vitamin B3) to the consumers. Organic peanuts acts as small protein enriched capsules which are healthy and affordable. They are mostly recommended as healthy snacks and widely consumed as a part of weight-loss lunch (Reddy *et al* 2019).

III. BIOFERTILIZERS APPROACH TOWARDS GROUNDNUT PRODUCTION.

India is one of the largest consumers of chemical fertilizers due to practice of intensive farming system. The use of chemical fertilizers has doubled in the last two decades that resulted in increasing cost of fertilizers and environmental degradation. Hence, a switch to bio-fertilizers can bring hopes for many countries both environmentally and economically (Gupta *et al*. 2003).

The bio-fertilizers act as source of microbial inoculates that can solve the problem of high cost of chemical fertilizers and their effect on our Eco-system (Gupta *et al* 2003). The uses of bio-fertilizers are considered as a long term sustainable practice. In agriculture ecosystem microorganisms play a vital role in fixing/mobilizing/recycling nutrients. These microorganisms are naturally present in the soil but in a very less amount. So in order to ensure soil health we should provide the soil with sufficient amount of microbes or else ensure their population is maintained. To increase the crop yield desired microbes are isolated, artificially cultured and mixed with suitable carriers and incorporated into the soil. These are called bio-fertilizers or microbial inoculates. Bio-fertilizers used in groundnut production include *cyanobacteria, acerbate, spiritualism, phosphate solubility microorganisms, carbuncular haemorrhagic, plant growth promoting cyanobacteria etc* (partisanship.2017).

In contrast to chemical fertilizers, bio-fertilizers are receiving attention and recognition from scientists because the microbial inoculates (including e.g. Rhizome and mycorrhizal fungal inoculants) introduced into soil or plant culture enhance plant productivity directly or indirectly (Mahdi,1992).Application of *Rhizobium and phosphobacterium* helps in achieving maximum shoot length, high number of branches per plant and leaf area index that resulted in high dry matter production (Chetti *et al.* 1995).

These bio-fertilizers contain living cells of nitrogen fixing organisms, phosphate mobilizing or fixing organism and phosphate mobilizers or fixers that helps in promoting plant growth by providing them with sufficient plant nutrients (Nisan subdivide.2017).

Generally in groundnut, seed treatment is done by mixing of seeds with bio-fertilizers in a plastic container since groundnut seeds are bigger as compared to other crop seeds. Through FYM, fertilizers can be provided by mixing them both and applying them in set furrow after which seeds are sown and irrigation is providing (partisanship 2017). Practice of fertigation provides many benefits including increased crop productivity and quality, efficient use of resources and environmental safety due to its role in reducing leaching of nutrients. Fertigation is practiced in groundnut cultivation in which liquid bio-fertilizers are diluted properly and applied in irrigation channel to spread uniformly. This helps in maintaining viability of cells (kisansuvidha.2017).

IV. ORGANIC MANURES AND THEIR SIGNIFICANCE IN GROUNDNUT CULTIVATION

Organic manures are mainly used for supplying plant nutrients in an efficient way along with improved soil conditions(Muhammad Ibrahim *et al.*2008).Organic manure has a strong positive impact on improving soil physical, chemical and biological properties and on increasing crop productivity. There are various studies suggesting that use of organic manures for a long time improved plant growth significantly (Muhammad Ibrahim *et al* 2008). FYM is a valuable organic fertilizer that helps in maintaining soil fertility (Järvan *et al.*2017). Suryanarayana Reddy in 1991 have reported that application of FYM has increased shelling percentage by 10%, 100 kernel weight by 32%, number of pod and pod yield in groundnut crop (P.Veeramani *et al.2011*). FYM not just act as a source of nutrient but also improves soil physical conditions that help in producing higher yield (Jagdev and Singh, 2000). According to the report of Balasubramanian and Palaniappan (1994), production increased in groundnut due to application of FYM along with microbial inoculants. FYM makes nutrients readily available to the plants by stimulating microbial activities in the soil(Dharma 1996). In groundnut production, incorporation of FYM in combination with poultry manure helps in increasing post-harvest soil organic carbon and calcium content in the soil (Das *et al.*1992). Fertilization with FYM in groundnut has reported increased kernel yield, highest dry matter accumulation, and oil content (Ahmed *et al*.1997). FYM application resulted in increased release of macro and micro nutrients that in turn increased dry matter production in groundnut (Dosani *et al* 1999). It also helps in avoiding potassium depletion in soil, maintaining positive potassium balance and increased availability of phosphorous (Akbari *et al*. 2002).

Poultry manure plays a significant role in organic farming due to its ability to enhance soil microbial activity, soil carbon, nitrogen content and porosity. Availability of macro (N, P, K, Ca, Mg, S) and micro-nutrients (Cu, Fe, Mn, B) in soil can be ensured with the application of poultry manure which act as a cheap source for these nutrients (P. Veeramani *et al* 2011). Poultry manure is important to maintain optimum physical condition of soil and for healthy plant growth (Rahman, 2004). In groundnut production, application of poultry manure improves number of pod per plant, pod yield and haulm yield (Subrahmaniyan *et al* 1999). Presence of higher proportion of nitrogen, phosphorous, potassium and other essential nutrients makes poultry manure an excellent choice as organic manure. Poultry manures works better than mineral fertilizers because it adds organic matter to the soil that helps in improving soil structure, aeration, soil porosity, and moisture holding capacity of soil and water infiltration (Deksissa. *et al* 2008).

Panchagavya is an organic product prepared using by-products of cow like cowdung , cow urine, cow milk, cow ghee ,cow curd and other ingredients (Gauthami.R *et al* 2014). Panchagavya helps in improving biological efficacy of crop plants (Nataraja 2002). In groundnut production, application of panchagavya along with neem leaf extract during branching and flowering helps in enhancing nutrient content, nutrient uptake, plant physiological characters, dry matter accumulation, chlorophyll content and yield attributes (Kumawat *et al* 2009).

V. ORGANIC PEST CONTROL: SUBSTITUTE TO SYNTHETIC PESTICIDES

There are a large number of insect pests associated with groundnut. Many of them are economically important. One of the major yield constraints of groundnut is insect pests (M.P Ghewande *et al* 1997).In India more than one hundred species of insects are reported in groundnut (Amin 1988; Nandagopal 1992). However, not all of them cause economic losses. Optimum integration of pest control and pest surveillance could result in maximum benefits in production of groundnut (M.P Ghewande *et al* 1997).

Even though chemical pesticides proved to be helpful in reducing pest attacks, their excessive use has resulted in major environmental issues. Their uncontrolled use has led to deterioration of beneficial organisms present in the soil and also resulted in pesticide residual problems and development of pesticide resistance in pest population. Hence IPM acts as a better alternative for pest management by providing sustainable methods of pest control (M.P Ghewande *et al* 1997).

There are many predators and parasites with power to cause mortality in aphids like

Menochilus sexmaculatus Fab., Coccinella repanda Thumbeg. var. transversalis Fab., C. maculata, C. septempunnctata, Brumus suturalis Fab and *the syrphids, Ischiodon scutellans Fab. and I. javan. Anthocoris sp. and Chrysopa carnea (chrisopidae*) (Amin 1988; Bakhetia and Sidhu 1976; Upadhyay and Vyas 1987).

There are some spiders and lygacied bugs that prey on jassids in groundnut but not cause major change in their population (Amin 1988).For jassids such as *E. kerri Pruthi, B. hortensis and Exitianus taeniaticeps (Kirchbaum)* there are preys belonging to species *Crassopalpus,* Empididae, Diptera (M.P Ghewande *et al* 1997).

According to the report from Junagadh , three species belonging to Heteroptera and four belonging to Salticidae (Spiders) act as predators of *c.indicus* (Nandagopal 1992).

The larvae of leaf miners can be controlled with the help of *Aspergillus flavus* which parasitize on them (Oblisami *et al* 1969).

Cultural control methods are integral part of pest management that include use of mulches, intercropping, crop rotation and other agronomic practices for control of pests.

Larvael population in groundnut can be controlled by inter cropping of groundnut with cowpea. *Pennisetum typhoidus* can also be inter-cropped with groundnut to achieve low incidence(20.8%) of leaf miner, resulting in higher income (Murali Baskaran and Thangavelu 1990). Foliage treatment of groundnut with 10% *P. typhoidus* leaf extract in water can reduce egg laying in leaf miner by 74%. (Murali Baskaran and Thangavelu 1990). Thrips can be controlled by sowing of crops at the onset of rainy season. According to the study conducted by Wightman and Amin at 1988, pest incidence can be reduced by 10% by practicing intercropping or multi-cropping of groundnut with cereals.

VI. ADVANCED DISEASE CONTROL METHODS IN GROUNDNUT

Discussion on replacement of synthetic fungicides has gained significance in the recent years due to the increasing price and environmental hazards caused by them. Apart from that, resistance developed by pathogen population against fungicides also possesses serious threat. Hence it is very important to provide an organic alternative to these problems (Ghewande *et al*. 1997).

Soil born pathogens act as one of the main reason for occurrence of diseases in groundnut. Among these, stem rot(collar rot) caused by *sclerotium rolfsii* plays major role. According to Mayee and Datar (1988) this disease can cause severe damage during any stage of the crop and can result in a yield loss of 25%. This can be controlled biologically through integrated pest management where combined application of *Rhizobium* and *Trichoderma harzinum* is applied. These microbial agents along with disease resistance also promote plant growth (S.Ganeshan *et al.* 2006).

Ghewande 1989; McDonald *et al*. 1985; Subrahmanyan *et al* 1990 had found that the Early and late leaf spot pathogens can be controlled using fungus *Dicyma pulvinata* (*Hansfordia pulvinata*) and *Verticillum lecanii* with their parasitic nature.Control of *P.arachidis* pathogen that causes rust on peanut can be done with the help of bio-agents like *Acromonium persicinum, A. salmonaum, Darluca filum, Eudarluca caricis, Tuberculina costaricana, Penicillium islandicum and V.*

*lecanii.s (*Ghewande 1990b; Sharma and Agarwal 1988; Sharma et al. 1990; Subrahmanyan and McDonald 1987; Yadav *et al*. 1987*)*.

Rust control at a rate of 66% is done with the help of spray application of cultural filtrates of both *P. islandicum* and *V. lecanii.* Size and number of lesions caused due to late leaf spot can be reduced with the help *V.lecanii* under field conditions (Ghewande 1989 and 1990).

Glucan isolated from, Acremonium obclavatum, is used to protect groundnut against the rust disease. Treated leaves showed a huge reduction in development of rust disease with increased amount of salicylic acid and chitinase. (Sathiyabama.M,Balasubramanian.R *et al* 2018).

The cultural methods involved in reduction of rust and leaf spot diseases in groundnut involves crop rotation, removal of volunteer groundnut plants, and removal of infected crop debris(McDonald and Raheja 1980; Subrahmanyan and McDonald 1983).One more method that could help in reducing incidence of leaf spot and rust is by practising early sowing of groundnut. (Ghewande et al. 1986; Kodmelwer and Ingle 1989; Siddaramaiah et al. 1980; Smith and Littrell, 1980).

Plant population density alternation is proved to be an effective method in reducing foliar disease severity (Ghewande *et al*.1986; Kodmelwer and Ingle 1989). Intercropping is one of the most successful methods in controlling rust and leaf spot diseases. Intercropping of groundnut with cowpea, sorghum, pearl millet and black gram is commonly practiced inorder to control these diseases. Pigeon pea and castor can also be used as successful intercrops for controlling rust and leaf spot (Ghewande *et al*.1993; Ghewande *et al*. 1986).

Aspergillus crown rot in groundnut can be controlled by practicing crop rotation of groundnut with other plants like wheat and gram (Sathiyanarayanamurthy *et al*. 1988).

A change in occurrence of root rot caused by *M.phaseolina* was observed when the groundnuts were planted with a spacing of 30 cm between them in a row as compared to the spacing of 45 cm or 60cm (Sharma 1982).

Control method of stem rot includes early sowing of crop and reducing of space between the plants (Ghewande 1983).Stem rot can be controlled effectively with the help of practices such as preventing organic matter development, burial of organic matter before planting , field sanitization etc (Garren 1964). Proportion of plants infested with bud necrosis can be reduced by increasing the plant density (Reddy *et al*.1983). Other than this, intercropping with pearl millet and early sowing can also diminish the chance of bud necrosis occurrence (Ghanekar 1980).

Soyabean, cowpea and navy bean serve as inoculum of peanut mottle virus hence it is recommended to cultivate groundnut away from these plants (Demski and Kuhn 1983).Clump disease caused by peanut clump virus in groundnut that result in stunted plant growth and many other symptoms can be controlled by growing groundnut during rabi season (Reddy 1988).

Diseases caused due to nematodes can result in huge loss in the groundnut farming, so it is very important to ensure their effective management. This can be done with the use of oil cakes, neem cakes, and other organic amendments along with deep ploughing during summer months (D.J. Patel, personal communication).Root-knot nematode species like M. arenaria are controlled by practicing crop rotation of groundnut with cereals and other crops like sesamum, castor and cotton (Rodriguez–Kabana and Morgan–Jones 1987; Rodriguez Kabana et al. 1991).

Peanut Stripe Virus (PStV) can be a serious threat to groundnut, if not managed properly. It can result in stunted plant growth and low pod yield. Cultural control practices of PStV include mixed cropping, inter cropping, use of non-legume plants for rotation, removal of weed host from the field, field sanitization, roughing, and burning down of infected plants. Hosts of PStV virus like legumes and sesamum should not be cultivated near groundnut (Singh *et al*. 1993).

VII. CONCLUSION

From the study, i conclude that, organic production of groundnut support sustainability and environmental well-being by reducing the input of synthetic pesticides and insecticides in the field. Use of naturally available inputs such as bio fertilizers and other organic matters are involved in improving the soil health and ensures maximum yield.

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Use of Basil *Ocimum basilicum and Chrysoperla externa* (Chrysopidae) in Agroecological Management of Rosebushes

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***Abstract*—** *The intensive cultivation of flowers in a greenhouse often presents low diversity of plant species and this limits the preservation of natural enemies for pest control. Floral resources may provide multiple ecosystem services and promote regulation of pest populations in greenhouses. Chrysoperla externa (Chrysopidae) is a predator of various pests in the Neotropical region. The purpose was to evaluate the effect of basil (Ocimum basilicum) and C. externa releases on agroecological pest management in rosebushes and compare it with conventional management. The greenhouse with rosebush 'Carolla' was divided in two parts, one side with diversified rosebush (rosebush + basil + C. externa releases) and the other side with conventional rosebush (insecticides, acaricides and fungicides). Arthropods were sampled weekly in the rosebushes and basil. The abundance and diversity were different between the systems evaluated. Greater abundance of natural enemies and pollinators was observed in the diversified rosebush. Basil has attracted a greater diversity of natural enemies and had a positive effect on pest control in the rosebush. In conventional rosebushes most insects were phytophagous. The production and quality of roses were not influenced by the treatments. Agroecological pest management favors the biological control in rosebush cultivation in greenhouse.*

***Keywords*— Biological control, Floral resources, Habitat management, Natural enemies, Roses.**

I. INTRODUCTION

Cultivation in the greenhouse has been extensively used by farmers and flowers and ornamental plants comprise about 650,000 ha in the world [1]. The estimate in Brazil is approximately 30,000 ha with greenhouses and the production of flowers represents about 10% of this area being the rose the most produced and commercialized cut flower [2].

One of the main issues associated with the loss of quality of flowers during cultivation refers to the pest arthropod infestation, affecting plant growth, flowering and causing aesthetic damage to floral buds. The most widely used pest control in flower production is still the chemical one, which has been causing problems of resistance and insecticide residues, besides affecting the populations of natural enemies and may contaminate workers and the environment [1,2,3].

The biological control of pests has been widely used in ornamental cultivation in greenhouses, which is mainly based on periodic releases of predators and parasitoids, that is, in the augmentative biological control [2,4]. Nevertheless, the effectiveness of this method may often be insufficient due to the difficulties of establishment and persistence of natural enemies in this environment [4,5], since intensive cultivation of flowers in a greenhouse usually presents low diversity of plant species, which limits the preservation of natural enemies for pest control.

Habitat management, through plant diversification, is a tool used to regulate pest populations in greenhouses. The conservative biological control can improve the establishment and maintenance of biological agents in the greenhouse. Studies have shown that more diversified agricultural systems can promote increased species richness and/or abundance of natural enemies of pests [5,6,7]. The use of flowering plants (floral resources) may promote the establishment and support of natural enemies' populations, with the aim of improving the control of pests such as aphids, thrips, among others [6,7,8,9,10,11]. Selecting the plant with adequate floral resource is an important factor to promote the attraction and accessibility of natural enemies in the cultivation area.

The predator *Chrysoperla externa* (Neuroptera: Chrysopidae) is an efficient pest controller of various pests such as aphids, lepidopterans, among others, with 100,000 to millions of individuals being commercialized per week in Latin America [2]. This species' adults are highly mobile, have a high reproduction rate and their larvae are voracious and have a great capacity for foraging [12]. In rosebush cultivation, research has been conducted aimed at the effective using of this predator as a biological control agent [10,13].

Basil (*Ocimum basilicum* L.) is an aromatic plant widely used in cooking and in the cosmetics and perfumery industry. Studies have shown basil being used as an attractive plant to different predators and parasitoids [11,14,15]. Agroecological pest management is aimed at promoting the balance of the system by reducing the pest population and increasing the population of beneficial insects. Thus, the purpose of this work was to assess the effect of basil as an attractive plant and of releases of *C. externa* in agroecological pest management on rosebushes in greenhouse and compare it with conventional management.

II. MATERIALS AND METHODS

The experiment was conducted from October to December 2016 in Minas Gerais, Brazil, at an altitude of 2917 ft. and geographical coordinates 21°06' S and 44°15' W. The local weather is mild (Cwa, according to the Köppen classification), which is characterized by humid summer and dry winter. The greenhouse (59 ft. x 19.7 ft.) was divided into two equal parts, transversely separated by a plastic (6.6 ft. high x 19.7 ft. long). On one side a diversified rosebush (agroecological management) (rosebush + basil + *C. externa* releases) was cultivated and on the other side rosebush with conventional management (insecticides, acaricides and fungicides). Each side of the greenhouse held 200 roses distributed in four flowerbeds with 50 plants per bed. We used 'Carolla' rose, which has a dark red color, velvety petals, and is well accepted in the market. The rosebushes were grown in single rows with spacing of 3.94 ft. between flowerbeds and 0.66 ft. between plants. The cultural treatments such as fertilization, irrigation, weeding, and pruning were carried out in both areas when necessary.

In the diversified rosebush cultivation, ten basil pots were planted on the sides of the greenhouse. Basil seedlings were planted in pots (2.6 gallons) containing soil and commercial substrate (Plantmax®) in a 2:1 ratio. Basil was used when in full bloom and approximately 19.68 in high. The second and third instar larvae of *C. externa* used in the releases were reared at 25±2ºC, relative humidity of 70±10% and photophase of 12 hours. Eggs up to 24 hours' old were individualized and after hatching the larvae were fed with eggs of *Anagasta kuehniella* (Lepidoptera: Pyralidae) until they reached the second and third instars to be used in the releases. The first release of *C. externa* was made seven days after the beginning of arthropod sampling. Later, two other releases were made every 20 days, totaling three releases during the experimental period. The chrysopid larvae were released in the ratio of two larvae per plant, totaling 400 chrysopid larvae per release. The larvae were released between eight and nine a.m., in the middle part of randomly chosen rosebushes in the beds.

In conventional rosebushes cultivation, the management and cultural practices normally used by the farmer were adopted, that is, phytosanitary treatments with chemical products (insecticides, acaricides, and fungicides) at a fixed schedule and without pest monitoring, applied once a week, with mixtures of up to three products. The insecticides and/or acaricides used were: abamectin (Abamectin Nortox®; 1.69 Oz 100 L^{-1}), propargite (Omite 720 EC®; 1.01 Oz 100 L^{-1}), fenpropathrin (Danimen 300 EC®; 0.84 Oz 100 L^{-1}), chlorfenapyr (Pirate®; 1.69 Oz 100 L^{-1}), pyriproxyfen (Cordial 100®; 2.7 Oz 100 L^{-1}), dimethoate (Dimexion®; 2.7 Oz L^{-1}), acetamiprid + pyriproxyfen (Privilege®; 100 g 100 L^{-1}) and mineral oil (Agefix®; 1 L 100 L^{-1}). The fungicides were: chlorothalonil (Daconil BR®; 0.44 lb 100 L^{-1}), tebuconazole (Tebuconazole CCAB 200 EC®; 2.53 Oz 100 L^{-1}), thiophanate-methyl (Cercobin 700WG®; 0.15 lb 100 L^{-1}), boscalid + kresoxim-methyl (Collis®; 1.69 Oz 100 L^{-1}), mancozeb (Alicerce®; 0.44 lb 100 L^{-1}), pyraclostrobin (Comet®; 1.35 Oz 100 L^{-1}) and mancozeb + metalaxyl-M (Ridomil Gold MZ®; 0.22 Oz 100 L^{-1}).

Weekly samplings of arthropods present on both the rosebushes in each treatment and on the basil were conducted. Evaluations started seven days prior to the first release of *C. externa*, totaling 10 evaluations. Samplings on the rosebushes were based on the number of arthropods present on three leaves per plant, which were randomly taken in the upper, middle, and lower thirds of each sampled plant [16]. Twelve rosebushes were randomly sampled per flowerbed, totaling 48 plants evaluated per treatment. Sampling of basil was done by beating the aerial part of the plant on a white plastic tray to dislodge the arthropods present, which were suctioned using a manual aspirator. All sampled arthropods were subsequently transported to the laboratory for counting and identification. Taxonomic classification of arthropods was carried out with the aid of specific dichotomous identification keys. Arthropods were classified into phytophages, predators, parasitoids, and pollinators. The yield and quality of flowers produced in each treatment (diversified rosebush or conventional rosebush) were also evaluated by counting the number of stems harvested at the commercial harvest point in each treatment. The commercial harvest point comprised the phase in which the petals of the extremity of the floral bud were curled together forming a well-defined spiral. Thus, stems were considered commercially produced when they were straight, without twisted flower buds or any other formation defects and with lengths of 15.75, 19.68 and 23.6 in [17].

Data concerning the sampling of all arthropods captured in the diversified rosebush, conventional rosebush, and basil plants were subjected to homogeneity of variance analysis and compared by the Kruskall-Wallis test ($p<0.05$). Graphical analyses of the arthropods found in the diversified rosebush and conventional rosebush were conducted. The ecological parameters of abundance (N); Shannon's diversity index (H') and Simpson's dominance index (D) were estimated. Pearson's linear correlation analysis ($p<0.05$) was conducted to evaluate the relationship of aphid abundance with the population of the natural enemies sampled in the diversified rosebushes. All tests were conducted using PAST® Software version 4.05 [18].

III. RESULTS AND DISCUSSION

A total of 3,122 arthropod specimens were sampled in the diversified rosebush, the conventional rosebush as well as in the basil plants. The collected arthropods belonged to 13 different taxa (Table 1). A greater abundance of specimens was observed in the diversified rosebush (2,222 specimens) compared to the conventional rosebush (423 specimens) and basil (477 specimens) (Table 1).

TABLE 1
TAXONS, ABUNDANCE, RELATIVE PERCENTAGE RECORDED IN THE DIVERSIFIED ROSEBUSH (rosebush + basil + *Chrysoperla externa* release), CONVENTIONAL ROSEBUSH AND BASIL

Taxa	Conventional		Diversified		Basil	
	Total	%	Total	%	Total	%
Aeolothripidae (P)	0	0	0	0	35	7.3
Aleyrodidae (F)	90	21.27	10	0.45	0	0
Anthocoridae (P)	0	0	0	0	29	6.07
Aphididae (F)	43	10.18	1175	52.9	0	0
Apidae (Po)	0	0	0	0	238	49.9
Araneae (P)	0	0	16	0.72	90	18.86
Braconidae (Pa)	0	0	74	3.33	0	0
Chrysopidae (R)	0	0	5	0.22	4	0.83
Coccinellidae (Po)	0	0	724	32.58	11	2.3
Ichneumonidae (Pa)	0	0	0	0	46	9.7
Miridae (P)	0	0	27	1.21	0	0
Syrphidae (P)	15	3.54	55	2.47	24	5.04
Thripidae (F)	275	65.01	136	6.12	0	0
Abundance (N)	423	100	2222	100	477	100
Shannon (H')	0.96		1.205		1.526	
Simpson (D)	0.5205		0.6085		0.6939	

***Ecological strategies F= Phytophagous, P= Predators, Pa= Parasitoids, Po= Pollinators**

The main phytophagous arthropods that were found on the rosebush belonged to the families Aphididae (aphids), Thripidae (thrips) and Aleyrodidae (whiteflies). The aphids species collected were *Aphis gossypii, Macrosiphum euphorbiae, Macrosiphum rosae, Myzus persicae and Rhodobium porosum* (Hemiptera: Aphididae). The thrips species collected were *Frankliniella occidentalis, Frankliniella shultzei, Thrips tabaci* and *Caliothrips phaseoli* (Thysanoptera: Thripidae). The whitefly species sampled was *Bemisia tabaci* biotype B (Hemiptera: Aleyrodidae). These phytophagous species are considered important pests in rosebush cultivation [2,3,10,13,16].

In the diversified rosebush area, the aphids were the most abundant phytophagous arthropods with 1,175 specimens collected (Table 1, Fig. 1). No damage was observed on the rosebushes in this treatment due to aphid attack. This was possibly due to the biological control provided by the chrysopid releases in the area, as well as the natural control provided by the natural enemies present on this side of the greenhouse (Table 1, Fig. 1). Several insects can be kept at densities below damage levels by natural enemies that naturally occur in the crop, such as predators and parasitoids that invade the greenhouse and result in a natural control of the pest [2,3].

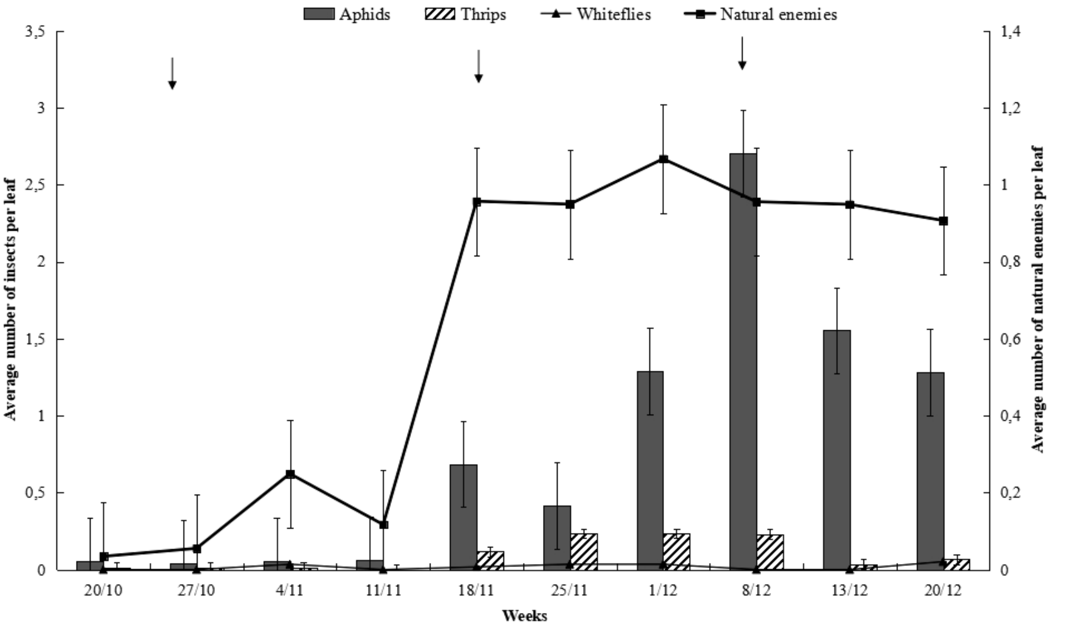

FIGURE 1: Average number of aphids, thrips, whiteflies and natural enemies per leaf of diversified rosebush (rosebush + basil + *Chrysoperla externa* releases) in the greenhouse. *Vertical arrows show the three releases of *Chrysoperla externa* larvae.

Among the natural enemies sampled in the rosebush and basil, we verified the presence of predators such as chrysopids (*C. externa*), ladybugs *Cycloneda sanguinea, Hippodamia convergens, Eriopis connexa, Psyllobora* sp. and *Scymnus* sp. (Coccinellidae), pirate bugs *Orius insidiosus* (Anthocoridae), predatory mirids *Hyaliodes beckeri* (Miridae), predatory thrips *Franklinothrips vespiformis* (Aeolothripidae), syrphids *Allograpta exotica, Pseudodorus clavatus* and *Toxomerus* sp. (Syrphidae) and spiders (Araneae). The parasitoids sampled were *Praon volucre* (Braconidae) and *Pimpla croceiventris* (Ichneumonidae). Most of these species have a polyphagous feeding habit and may be responsible for population control of different herbivore-pests in the agroecosystem [7,8,9,10,13,14,16].

In the diversified rosebush (rosebush + basil + *C. externa* releases), it was observed higher abundance of natural enemies (H: 13.17; p= 0.0001423), predators such as ladybugs (Coccinellidae), green lacewings (Chrysopidae), mirids (Miridae), syrphids (Syrphidae), spiders (Araneae) and parasitoids (Braconidae), having a total of 901 specimens collected, compared to the conventional rosebush (Fig. 2).

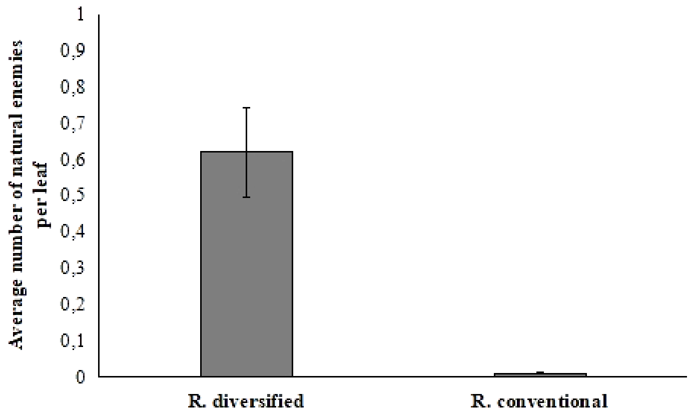

FIGURE 2: Average number of natural enemies per leaf in diversified rosebush (rosebush + basil + *Chrysoperla externa* releases) and in conventional rosebush in greenhouse. Treatments differed from each other by Kruskal-Wallis test at 5% probability.

The natural enemies found in this study may have contributed to the reduction of the population of phytophagous arthropods in the diversified rosebush cultivation. A significant and positive correlation, calculated by Pearson's coefficient, was found between the number of aphids and natural enemies present per rosebush leaves in the diversified area (r = 0.9229; P = 0.00014075) (Fig. 3). These results showed that natural enemies (ladybugs, green lacewings, pirate bugs, mirid bugs, syrphids, predatory thrips, spiders, and parasitoids) had significant and high correlations when not exposed to chemical insecticides, showing that these control agents can respond numerically to increased aphid infestation on rosebush and control their populations. This dependence between these insect groups may be associated with ecological relationships among them.

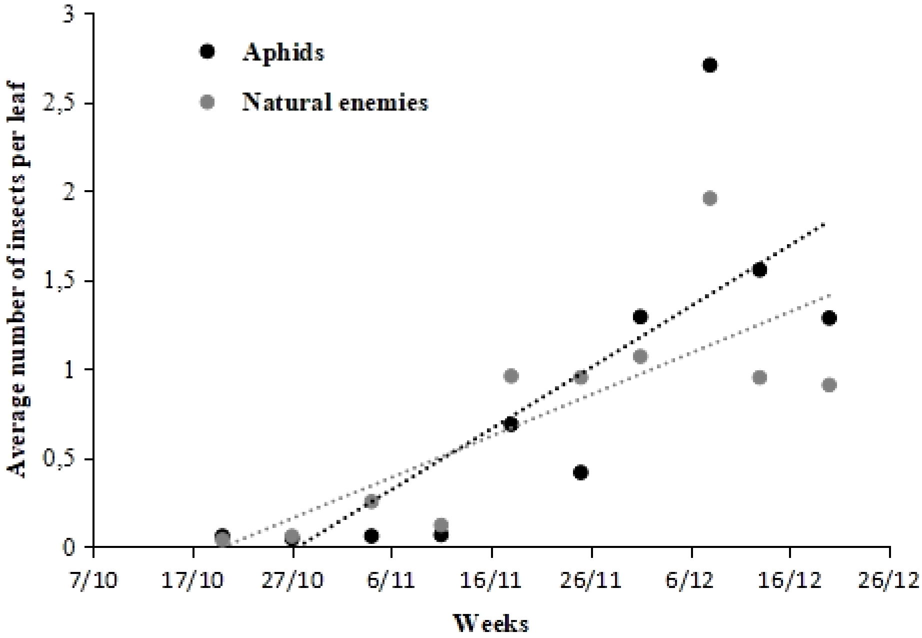

FIGURE 3: Average number of aphids and natural enemies per leaf of diversified rosebush (rosebush + basil + *Chrysoperla externa* releases) in greenhouse.

Constant and increasing presence of natural enemies was observed in the diversified rosebush cultivation area (Fig. 1), and this fact may be related to the use of basil as an attractive plant on the sides of the greenhouse. The fact that the basil plant had a constant bloom during the whole experimental period may have contributed to the attraction of a greater diversity of natural enemies to the area of diversified roses. This fact has also been confirmed when the diversity of species in the different treatments was evaluated, because it was verified a relatively high diversity by both Shannon-H index and Simpson index (H' = 1.205, D = 0.6085) in the diversified rosebushes, as in basil (H' = 1.526, D = 0.6939) (Table 1). These results demonstrated that the association of rosebushes and basil attract and host major natural enemies and that there is an increase in the abundance of these insects due to the availability of alternative food resources, mainly associated with basil flowers. According to [19] the long flowering period of basil, which lasts from three to four months, can benefit the combined crop by attracting beneficial insects and pollinators, since its flowers are considered a source of nectar with high sugar production.

Chrysopids assisted in reducing the aphid population in the diversified rosebush crop. After the releases of *C. externa* larvae there was a decrease in the occurrence of aphids on the rosebushes (Fig. 1). Studies show that *C. externa* larvae feed on aphids causing a decrease in their populations [10,13]. Despite the release of *C. externa* in the diversified rosebush, five specimens were found in the diversified rosebush and four in basil (Table 1). This difficulty in finding the chrysopids in the evaluations may have occurred due to the behavior of this predator, since this insect predator has a nocturnal habit, and the evaluations were made in the morning period. During the day, the adult chrysopids remain most of the time at rest on the lower surface of the leaves and the larvae remain inside the plants [20].

Adults of *C. externa* are not predators and mainly feed on sugary substances such as honeydew, floral and extrafloral nectar, and pollen [7,8,10]. These alternative food sources may be found in abundance in basil, which may be an important food source for this and other predators. Pollen from various botanical families were observed in the digestive tract of *C. externa* showing the importance of plant diversification in the growing area [7].

Among the predators sampled in the diversified rosebush the ladybugs were the most abundant with 724 specimens. This may have occurred because of the presence of prey in the diversified area and also because of the presence of basil that was constantly in bloom thus favoring the permanence of this predator in the area. Our results are consistent with [5] who reported that ladybugs apart from feeding on prey, also need floral resources such as pollen and nectar, which are able to ensure the survival of adults and sustain the metabolism and development of the young phase of this predator and the results of [9] when studying the influence of the association of kale with flowering plants, also found significantly higher numbers of individuals and species of these predatory insects in diversified cultivation, when compared to isolated cultivation.

In the samplings conducted on basil plants, a total of 477 specimens were collected, with pollinating insects (bees) being the most abundant with 238 specimens collected, among them *Apis mellifera* (Apidae) and other individuals of the Apidae family (Table 1; Fig. 2). Floral resources of basil provided higher pollinator richness and abundance, mainly *A. mellifera*, in sweet pepper crop associated with basil, compared to sweet pepper alone [19].

The spider group was the second most abundant taxon in basil, with 90 specimens collected, and their presence was observed in almost all collections. Spiders are predators of aphids and other arthropods and may be observed in various types of crops, as well as being bioindicators of environmental quality [21].

In basil, syrphids, thrips predators, parasitoids, spiders, pirate bugs, ladybugs and green lacewings were also sampled (Table 1). The constant presence of different beneficial insects that are attracted to the basil plant may have helped to reduce the aphid population and other phytophages in the diversified roses.

In order to control pest populations in commercial crops, the natural enemies must be nearby the plants prior to the outbreak of pests and this can only be achieved by first attracting these biological agents and providing conditions for their establishment in the area [7,8,10], since the population of natural enemies depends on the pest population, if there is no availability of other food resources the efficiency of biological control is impaired, because of the rapid increase of arthropod-pests. The use of basil combined with sweet pepper cultivation made it easier to install *Orius laevigatus* (Hemiptera: Anthocoridae), an important predator of thrips, aphids, whiteflies and mites [14]. Basil flowers have provided higher survival for larvae and adults of *Ceraechrysa cubana* (Neuroptera: Chrysopidae) and the use of *O. basilicum* as a diversification component in agricultural areas may be of benefit in attracting and maintaining *C. cubana* populations favoring biological control [11].

The diversified rosebush crop was the closest to the predator species found on basil. They shared 5 taxa, this may be beneficial to the rosebush crop because of the high number of predators and parasitoids found in the area. The Aeolothripidae, Apidae, Anthocoridae taxa were unique to basil and the Miridae taxon was unique to the diversified cultivation, being classified as predators or pollinators. This fact shows the importance of maintaining basil plants near the rosebushes in the greenhouse, since through the results found, it was observed that basil plants can serve as a reservoir for these predators. Authors have reported that in periods of scarcity of preys, natural enemies can use pollen and nectar from flowering plants nearby the cultivation area for feeding, as well as use these flowering plants as shelter and/or oviposition sites [7,8,11,14].

The higher abundance of predatory insects observed during the experiment in the diversified rosebush is in line with the "Natural Enemy Hypothesis" [22], where it states that biological control agents tend to be more abundant in diversified environments, because these provide shelter, sites for reproduction, which promotes the establishment and multiplication of these insects.

In conventional rosebushes, despite the repeated weekly spraying of chemical products, the occurrence of several phytophagous insects was observed, especially thrips, with 275 specimens sampled (Fig. 4). Furthermore, practically no natural enemies were observed during the sampling in the conventional rosebush (Fig. 4). This may have occurred because of the intensive use of non-selective chemicals (insecticides, acaricides, and fungicides) in this area. Several authors have reported that the use of chemicals is quite common in the cultivation of rosebushes, negatively influencing the populations of natural enemies, causing resistance problems and hindering the biological control of pests [1,2,3,4].

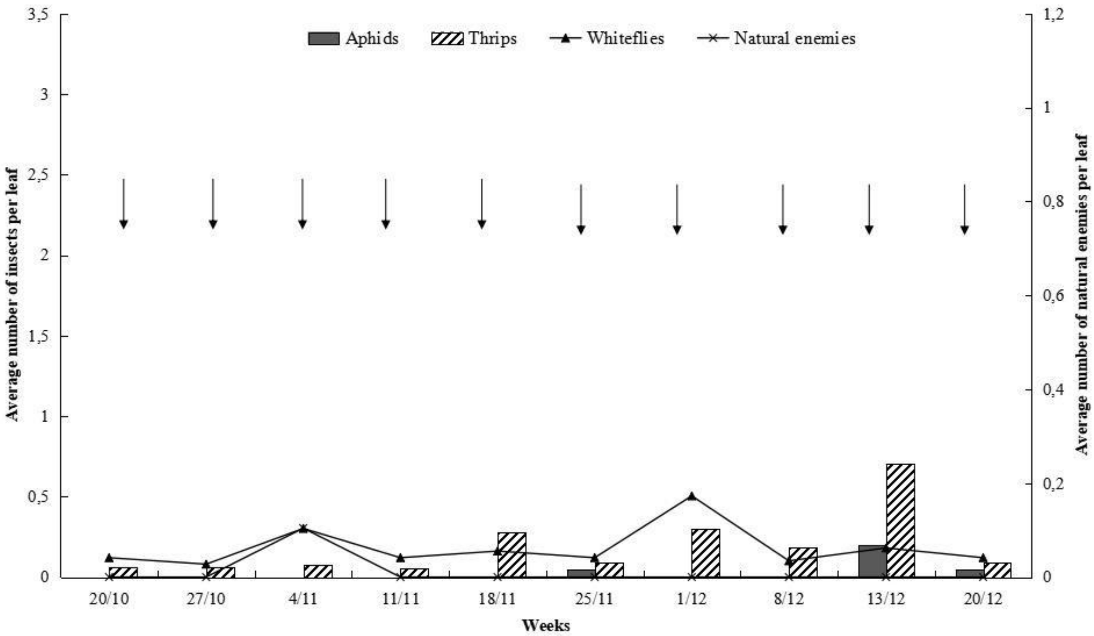

FIGURE 4: Average number of aphids, thrips, white flies and natural enemies in conventional rosebushes (sprays with insecticides, acaricides and fungicides) in a greenhouse. *Vertical arrows indicate weekly application of chemicals (insecticides, acaricides and fungicides).

As regards the productivity of rose floral stems, it was found that the number of stems harvested was not affected by the type of treatment evaluated, that is, an average of 57.9 stems were harvested in the diversified rosebush cultivation and 59.7 stems in the conventional rosebush cultivation. Moreover, it was verified that all harvested stems had the commercial quality standard, according to [17].

In view of the results obtained, it was possible to verify that the implementation of sustainable agroecological pest management practices in rosebushes, such as the combination of using basil as an attractive plant and chrysopid releases, favored biological control in the cultivation of rosebushes and did not affect the production and quality of the rose stems produced. In addition, no chemicals were applied in the agroecological rosebushes, thus avoiding problems of environmental contamination and residues in the flowers. However, further studies should be carried out in order to better understand the effect of basil on the conservative biological control of roses, because the knowledge of these ecological relationships may be important for bioecology studies and also as a tool for planning and implementing pest management in rosebushes.

IV. CONCLUSION

The combination of using basil as an attractive plant and chrysopid releases favors the biological control in the cultivation of rosebushes in a greenhouse. Basil associated with rosebushes provides greater abundance and diversity of natural enemies in rosebushes. Basil is a promising attractive plant for conservation biological control in roses. The production and quality of floral stems are not impaired by diversification of rosebushes with basil.

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Microbial and Nutritional Evaluation of Fresh and Wastewater Cultivated Cabbage in Quetta, Pakistan

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Abstract— *Using wastewater for agricultural irrigation presents potential risks to public health and the environment. The aim of this study was to compare the microbial burden and nutritional components of cabbage grown in fresh and wastewater in Quetta, Pakistan. Cabbage samples randomly collected from fields irrigated with fresh and wastewater sources were analysed for viable bacterial and fungal counts, pH and vitamin contents. There was a significant difference in viable bacterial (3.0×10^6, 1.9×10^7 CFU g^{-1}) and fungal (2.4×10^3, 1.0×10^5 CFU g^{-1}) counts for cabbage grown in fresh and wastewater, respectively. There were no significant differences in pH (7.88/7.86) and contents of the vitamins thiamin (0.31/0.30 mg/100 g), riboflavin (0.05/0.04 mg/100 g), niacin (0.56/.54 mg/100 g), pyridoxine (0.13/0.12 mg/100 g) and ascorbic acid (57.00/56.60 mg/100 g). Results demonstrated that cabbage grown in wastewater had a significantly higher microbial burden than cabbage grown in fresh water, although there were no significant differences in nutritional components of cabbage from the different water sources. These observations emphasise the potential dangers to public health in using wastewater for agricultural irrigation.*

Keywords— ***Agricultural irrigation, Bacterial count, Brassica, Public health, Vitamins, Water resources.***

I. INTRODUCTION

Vegetables have high water content and contain valuable nutrients such as carbohydrates, proteins, vitamins and minerals. These vital components are not only necessary for maintenance and buildup of the body but also in maintaining the alkaline reserve of the body (Hanif et al., 2006) and in repairing tissues and preventing various ailments (Bakhsh and Hassan, 2005; Lyaka et al., 2014; Lewu and Kambizi, 2015). An important *Brassica* vegetable is cabbage (*Brassica oleracea*), which is an herbaceous flowering plant with leaves forming a compact head and abundantly available in Pakistan for both human and animal consumption. Cabbage is low in calories and a good source of fiber, vitamin A, vitamin C, vitamin B_9, calcium and iron (Hossain et al., 2016). *Brassica* vegetables contain active ingredients such as 3,3-diindolylmethane, indole, isothiocyanates and dithiolthiones, which are reported to act as effective modulators to the inherent immune response, and effective anti-bacterial, anti-viral and anti-cancer agents (Zhang et al., 2014).

Consumption of green leafy vegetables has increased in recent years because of their nutritional significance and valuable health effects (Vandekinderen et al., 2008). Cabbage in Pakistan is mostly eaten raw as salad or added to fast foods such as burgers. It is also used as a cooked vegetable. Discarded cabbage as a vegetable by-product can be considered a potential non-conventional feed resource for ruminants. Cabbage may harbor a wide range of microbial contaminants, which undermine their nutritional and health benefits and may result in outbreaks of human infections from ingestion of fresh or minimally treated vegetables (Beuchat, 2002). Use of industrial and domestic effluents to irrigate agricultural land is a usual practice for wastewater disposal in Pakistan (Murtaza et al., 2010; Naz et al., 2016). Recurrent droughts, low rainfall and poorly performing irrigation structure increase water shortage and result in a widespread use of wastewater (Lone et al., 2000). Due to the presence of phosphorous and nitrogen, wastewater is a good source of plant nutrients, however (Nauman and Khan, 2010).

The current study was planned to compare influences of irrigation using fresh water (tube well) and municipal wastewater on the microbial loads and nutritional quality of cabbage.

II. MATERIALS AND METHODS

2.1 Sample collection

Cabbage samples (early cabbage, n=30, each ~1 kg) were randomly collected on three separate days (3 x 10 cabbages) from fields irrigated with fresh (tube-well) and wastewater sources, located near Smungli Road and Sabzal Road, Quetta. The samples were collected in pre-sterilized polyethylene plastic bags and immediately transferred to the Toxicology Laboratory of the Center for Advanced Studies in Vaccinology and Biotechnology (CASVAB) for preparation and analysis of their viable bacterial and fungal counts, pH and vitamin contents.

2.2 Sample preparation and drying

On the same day as collection, cabbage samples were washed with filter-sterilised water (0.2 μM) and then cut into 10 mm thick transverse slices using a vegetable slicer. Subsequently, they were dried under shade conditions with a maximum day temperature of approximately 37 °C and a minimum night temperature of approximately 20 °C. The cabbage samples were weighed at various intervals over the entire drying period until their weights became constant. The dried cabbage slices were milled using a laboratory pestle and mortar and the powders were stored in pre-sterilized polyethylene bags at room temperature.

2.3 Sample analysis

Viable bacterial and fungal counts were determined following methods previously adopted by Abdullahi and Abdulkareem (2010) and Magnoli et al. (2002), respectively. To estimate the pH, juice from 10 g of each cabbage was blended using a National 4100 electric juicer and the pH was measured using a Jenway 3510 pH meter. The vitamin contents including vitamin B_1 (thiamine), vitamin B_2 (riboflavin), vitamin B_3 (niacin), vitamin B_6 (pyridoxine) and vitamin C (ascorbic acid) were determined by Syknm reversed phase (RP) isocratic HPLC equipped with an S1122 solvent delivery system and an S3210 UV-visible detector adopting the methodology of Sami et al. (2014). The solvents and water used for analysis were HPLC-grade and all of the vitamin standards were of chromatography grade.

2.4 Determination of vitamin contents

Cabbage powder (2 g) was placed in 0.1 N H_2SO_4 solution (made up to 25 mL) and incubated at 121 °C for 30 min. The contents were then cooled and the pH was adjusted to 4.5 by addition of sodium acetate (2.5 M). Samples were treated with the enzyme Takadiastase (50 mg) and then held overnight at 35 °C. The mixture was filtered using Whatman No. 4 filter paper, and then the filtrate was diluted with water (50 mL) and filtered using a 0.45 μm syringe. A 20 μL sample of the filtrate was injected into the HPLC instrument and quantification of vitamin B content was accomplished by comparing with vitamin B standards. Standard stock solutions of riboflavin, thiamine, pyridoxine and niacin were similarly prepared. Chromatographic separation was achieved using a mobile phase containing 33:67 $CH_3OH:H_3PO_4$ (0.023M, pH = 3.54) with a flow rate of 0.5 mL/min. The absorbance at 270 nm was recorded at room temperature.

2.5 Vitamin C analysis

Cabbage powder (10 g in triplicate) was blended and mixed with an extracting solution containing metaphosphoric acid (0.3 M) and acetic acid (1.4 M). The mixture was placed in a conical flask and agitated at 10,000 rpm for 15 min. The mixture was then filtered through a Whatman No. 4 filter paper. The vitamin C standard was prepared by dissolving vitamin C (100 mg) in extracting solution at a concentration of 0.1 mg/mL. Chromatographic separation was achieved on a RP-HPLC column through isocratic delivery of a mobile phase containing 50:50 CH_3CO_2K (0.1 M, pH = 4.9):CH_3CN with a flow rate of 1 mL/min. The absorbance at 270 nm was recorded at room temperature.

2.6 Data analysis

The data was statistically analysed with SPSS 16 for Windows using the independent sample student's t-test.

III. RESULTS

The results of the VBC and VFC tests of the cabbage samples are given in Table 1. The VBC values had ranges of 2.8×10^6 to 3.2×10^6 and 1.7×10^7 to 2.2×10^7 CFU g^{-1} (mean 3.0×10^6 and 1.9×10^7 CFU g^{-1}) for fresh and wastewater, respectively. The VFC values had ranges of 1.8×10^3 to 3.0×10^3 and 8.0×10^4 to 1.2×10^5 CFU g^{-1} (mean 2.4×10^3 and 1.0×10^5 CFU g^{-1}) for fresh and wastewater, respectively. There were significant ($P<0.05$) differences in the values of VBCs and VFCs in both fresh and wastewater.

The pH values of cabbage samples (Table 1) had ranges of 7.86 to 7.90 and 7.85 to 7.89 (mean 7.88 ± 0.02 and 7.86 ± 0.02) for fresh and wastewater, respectively. There was no significant ($P>0.05$) difference in pH between fresh and wastewater resources respectively. The measured pH values were close to those of Anon (1962).

TABLE 1
BACTERIAL, FUNGAL AND pH ANALYSIS OF CABBAGE SAMPLES

Parameter	Source of irrigation			
	Fresh water		Wastewater	
	Range	Mean ± SD	Range	Mean ± SD
VBC	2.8×10^6-3.2×10^6	$3.0 \times 10^6 \pm 1.6 \times 10^{5b}$	1.7×10^7–2.2×10^7	$1.9 \times 10^7 \pm 1.9 \times 10^{6a}$
VFC	1.8×10^3-3.0×10^3	$2.4 \times 10^3 \pm 492^b$	8.0×10^4 – 1.2×10^5	$1.0 \times 10^5 \pm 1.6 \times 10^{4a}$
pH	7.86-7.90	7.88 ± 0.02^a	7.85 - 7.89	7.86 ± 0.02^a

Mean values with the same letter in a row were not significantly (P>0.05) different. VBC = viable bacterial count, VFC = viable fungal count.

The contents of water-soluble vitamins (thiamine, riboflavin, niacin, ascorbic acid) are given in Table 2. Cabbage cultivated using fresh and wastewater irrigation contains 0.31/0.29 mg/100 g of thiamine, 0.05/0.04 mg/100 g of riboflavin, 0.56/0.54 mg/100 g of niacin, 0.13/0.12 mg/100 g of pyridoxine and 57.00/56.60 mg/100 g of ascorbic acid, respectively with no significant difference ($P>0.05$) for the two water sources.

TABLE 2
VITAMIN CONTENTS IN CABBAGE SAMPLES

Vitamin	Source of irrigation			
	Fresh water		Wastewater	
	Range	Mean ± SD	Range	Mean ± SD
B_1	0.27-0.36	0.31 ± 0.04^a	0.26-0.35	0.29 ± 0.04^a
B_2	0.03-0.06	0.05 ± 0.01^a	0.03-0.05	0.04 ± 0.01^a
B_3	0.44-0.69	0.56 ± 0.1^a	0.41-0.67	0.54 ± 0.1^a
B_6	0.12-0.15	0.13 ± 0.01^a	0.11-0.14	0.12 ± 0.01^a
C	55.00-59.00	57.00 ± 1.58^a	53.00-58.00	56.60 ± 2.07^a

Mean values with the same letter in a row were not significantly different (P>0.05). B_1 = thiamine, B_2 = riboflavin, B_3 = niacin, B_6 = pyridoxine.

IV. DISCUSSION

Cabbage irrigated with wastewater showed significantly higher microbial (viable bacterial and fungal counts) contamination. The findings regarding VBC are in agreement with Pesewu et al. (2014), Nwankwo et al. (2015), Dada and Olusola-Makinde (2015) and Hasibur et al. (2016), and the findings regarding VFC are in line with the results of Oluwafemi et al. (2013), Nwankwo et al. (2015) and Dada and Olusola-Makinde (2015). The presence of a higher microbial population in wastewater compared with fresh water is a natural phenomenon. The dairy and home sewage water, that is an integral part of wastewater in Quetta, is not only contaminated with microorganisms but also contains organic matter that serves as good culture media for microorganisms, especially bacteria and fungi (Alemayehu et al., 2015).

The current study revealed presence of appreciable quantities of vitamin C in the cabbage samples. Vitamin C helps in the formation of protein, collagen, bone, teeth, gums, cartilage, blood vessels, skin and scar tissue (Agea et al., 2014), facilitates the absorption of iron and calcium from the gastrointestinal tract, is involved in metabolism of fats and amino, increases resistance to infection and contributes to brain functioning (Schectman et al., 1991). The results were in line with the observations of Hanif et al. (2006), Mariga et al. (2012), Roe et al. (2013), Agea et al. (2014) and Ogbede et al. (2015). The recommended daily allowance (RDA) of vitamin C for a healthy adult is 65 to 90 mg, which could be easily attained by the use of cabbage as part of a low calorie diet (Agea et al., 2014).

V. CONCLUSION

The results from this study in Quetta, Pakistan demonstrated that cabbage grown in wastewater has a significantly higher microbial burden than cabbage grown in fresh water, although there were no significant differences in nutritional components of cabbage from the different water sources. These observations emphasise the potential dangers to public health in using wastewater for agricultural irrigation. Hence there is a need for regulatory authorities to ensure that wastewater is used for irrigation only after treatment. Further microbiological standards should be established and followed by agriculturalists and sellers for the handling and dispersal of such vegetables. End users are advised to thoroughly rinse such vegetables with clean water before use.

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Production of Exportable Agricultural Commodities in Nigeria

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Abstract— *The aim of this study is to evaluate the production of exportable agricultural commodities (cocoa, cashew and ginger) in Nigeria. Three hundred and seventy (370) exporters were interviewed for this study. Findings revealed that half of the respondents' source for their seedlings through purchase of certified seeds. Almost 33.5% of the respondents plant Brazilian cashew, 30% plant both yellow and black ginger varieties while 37% of them majorly plant Forastero cocoa varieties due to their high demand. Results showed that most of the respondents (26.2%, 36.8% and 33.5%) supplied the highest volume of agricultural commodities (cashew, ginger and cocoa) in year 2012 and earn more in the same period. Findings indicated that land (36.2%) is the major cost component that had the highest impact while transportation (34.6%) is the main cost component that steadily increases among others. Government should provide services on trade support to aid access to global markets.*

Keywords— Production, agricultural commodities, exportable, cost.

I. INTRODUCTION

The agricultural sector is a significant sector in the economy of Nigeria because it serves as a foremost role in quick development of the country (Ayinde et al., 2015). Agriculture provides job opportunities for above 70% of the growing population, serves as source of food, foreign exchange earnings for the growth of industries and source of raw materials (Giroh et al., 2010). Despite the prevalence and important reliance of Nigeria economy on oil sector, agriculture still remains an important source of economic resilience and mainstay (National Economic Empowerment and Development Strategy, (NEEDS), 2004; Ayinde et al., 2015). Since 1970, agriculture performance in Nigeria noticeably revealed that its contribution is above 30% of the yearly Gross Domestic Product (GDP), provides above 80% of the food required of the nation; and likewise account for more than 70% of the exports of non-oil as cited by Ayinde et al. (2015). Succeeding crude oil, agriculture is the second biggest export earner but as a result of oil boom, the percentage contribution of agriculture to GDP drastically fall (Ayinde et al., 2015). It is vital to consider that Nigeria which happens to be a foremost exporter of numerous agricultural products such as rubber, groundnuts, cocoa and palm kernel has completely misplaced her governance place in the export of these agricultural yield (Mesike et al. 2007; Ayinde et al., 2015).

Regardless of the steady development in the worth of Nigeria's agriculture exports over the period of 2016 to 2018, the nation's agriculture exports to overall exports lingered beneath 2% (www.pwc.com; Onakoya et al., 2020). The nation's total export of agricultural commodities was motivated by export of crude palm kernel oil, ginger, fermented cocoa beans, soya beans, sesame seeds (broken or not broken), prawns, cashew nuts, frozen shrimps and agro foods. Cumulatively, from export of agriculture, the nation earned ₦0.53 trillion between the period of 2016 and 2018 whereas, total agriculture imports bill of Nigeria stood at ₦2.39 trillion over the same era (www.pwc.com). Due to this, deficit of agriculture trade stood at ₦1.86 trillion. Hence, the nation is a food importer. In 2019 between January to June, agricultural exports of Nigeria rose to ₦152.3 billion based on the released National Bureau Statistics (NBS) foreign trade information which covers the first and second part in 2019. Among the exportable agricultural commodities in Nigeria, sesame seeds remain the largest earner in the previous years, followed by fermented cocoa beans which is the second largest agricultural export whereas cashew nuts is the third leading agricultural export. Other agricultural products include Ginger and agro-food items (Nairametrics, 2019). Nigeria's biggest market for sesame seeds are China, South Korea, Belgium, Germany, Turkey and Japan; for cocoa include Malaysia, Belgium, Netherlands, Germany and Indonesia; while market for cashew nuts are Tanzania, India, Vietnam, Netherlands and Russia (Nairametrics, 2019). According to Onwusiribe et al. (2018), in Nigeria, ginger farmers are majorly dominated by smallholder farmers and are confronted by the inaccessibility of huge hectares of land for industrialized farming. Likewise, ginger price from Nigeria is unpleasant which is ascribed to its low quality from the country and as a result of this, it is not economical in the global market. The utmost challenges encountered in exportation of root and tuber in Nigeria is the low quality of production of ginger and supply. However, poor implementation of economic policy in the form of exchange rates, is also part of the challenges encountered in the international market of ginger (Onwusiribe et al., 2018). Furthermore, Cocoa Farmers Association of Nigeria (CFAN) reported in 2018 that their members encountered difficulties in the aspect of absence of funding from the government, unfavorable weather state and fake chemicals used by the farmers. Cocoa is crucial to the source of revenue of between 40 and 50 million people globally which also includes above 5 million smallholder cocoa farmers who cultivate this valued crop (Biney, 2017). According to International Institute of Tropical Agriculture (IITA), it was reported in 2017 that West Africa yields 70% of the global cocoa market which about 90% of these produce is generated from farms that are small consisting less than 5 hectares of land (www.iita.org).

The challenges Nigeria as are to transform increased agricultural production into upsurge exports. Despite determinations to develop the export of agricultural commodities via sequences of interventions, the expected outcomes were barely accomplished with the capacity of production still extreme beneath anticipation when associated to the volume in the early 1970s before oil boom (Biney, 2017). Meanwhile, agriculture sector is the leading supplier to the GDP of Nigeria, unraveling the prospects of agricultural exports is vital. Despite the lessen in agricultural exports, it contributes considerably to job opportunities in Nigeria. Therefore, the general objective of this study is to evaluate the production of exportable agricultural commodities (Cocoa, Cashew and Ginger) among exporters in Nigeria.

II. METHODOLOGY

The study was carried out in Nigeria which is positioned in the West Africa. The country shares boundaries with Chad and Cameroon to the East, Niger to the North and Benin towards the West. The nation lies between the longitudes 3^0E and 15^0E and latitudes 4^0N and 14^0N. The country has a tropical climate which consists of comparatively high temperatures all over the year with yearly mean temperature fluctuating from 31^0C in the south to 35^0c in the North. Furthermore, it consists of land area of around 923,769km^2 whereas the coastline is 853km (Onwusiribe et al., 2018). Agriculture is the major source of foreign exchange in Nigeria. Currently, the major exportable agricultural commodities in Nigeria include sesame seeds, fermented cocoa beans, cashew nuts, ginger and other agro-food items. This study is a cross-sectional data and exporters of cocoa, cashew and ginger in Nigeria were the respondents. From the list of exporters of cocoa, cashew and ginger farmers, three hundred and seventy (370) certified exporters of agricultural commodities (cocoa, cashew and ginger) were simple randomly selected for this survey. A well-structured questionnaire was planned and administered to exporters of agricultural commodities through google form link for easy filling. Data used for this study was obtained through the means. The questionnaire was divided into three sections; demographic, production of agricultural commodities and cost of production. Descriptive statistics was used for data analysis.

III. RESULTS

3.1 Demographic factors

The descriptive statistics of demographic factors of respondents in the study area is shown in Table 1. Findings revealed that the mean age respondents are 34.6 years. Result showed that maximum and minimum value of sex is 2 and 1 respectively. Furthermore, household size result indicated that the maximum value is 15 people while the minimum value is 1 people. Based on the educational level of respondents, findings showed that maximum value is 4 which imply that they have tertiary education while the minimum value is 3 which denote secondary education. Findings revealed that majority of the respondents do not have access to credit facilities.

TABLE 1
DESCRIPTIVE STATISTICS OF DEMOGRAPHIC FACTORS OF RESPONDENTS (n=370)

Variables	N	Minimum	Maximum	Mean	Std. deviation
Age (years)	370	26	58	34.6	.912
Sex	370	1	2	1.36	.480
Household size	370	1	15	4.81	3.284
Educational level	370	3	4	3.95	.210
Members of exporters association group	370	1	2	1.51	.501
Access to credit facilities	370	1	2	1.81	.390
Form of training	370	1	2	1.53	.500
Experience of exportation	370	1	20	5.84	4.379

Source: Field data survey and SPSS computation, 2021

3.2 Production of agricultural commodities (Cashew, Ginger and Cocoa)

Table 2 presents the descriptive statistics of production of agricultural commodities. Results revealed that above half (56%) of the respondents' export cashew, 87.5% of them export ginger and 50% of them export cocoa respectively. In terms of agricultural farm land used for cultivation of agricultural commodities, 55.7% of the respondents leased their land, whereas 22.7% specified that the land they used was offered to them by the community. Half of the respondents' source for their seedlings through purchase of certified seeds. Based on the percentage of farmland used for production, 26.5% of the respondents use between 40-60% for cashew production, 24.6% of them use between 21-40% for ginger production while 30.2% of them use between 61-80% for cocoa production. Most (35%) of the respondents plant Brazilian cashew, 30% plant both yellow and black ginger varieties while 37% of them majorly plant Forastero for cocoa varieties. However, half of the respondents (51.9%) indicated that they plant such varieties of agricultural commodities due to its high demand. Furthermore, findings revealed that 26.2%, 36.8% and 33.5% respondents supplied the highest volume of agricultural commodities (cashew, ginger and cocoa) in year 2012. The average selling price per tonnes for cashew is ₦807,298.5782, for ginger is ₦582,517.2414 and for cocoa is ₦959,012.8755 respectively. In terms of factors that affect production output, 48.1% of the respondents specified that market uncertainties are the major factor.

TABLE 2
DESCRIPTIVE STATISTICS OF PRODUCTION OF AGRICULTURAL COMMODITIES (CASHEW, GINGER AND COCOA)

Variables	Frequency	Percentage (%)
Agricultural commodities exported		
Cashew		
High	31	8.4
Low	176	47.6
Not at all	163	44.1
Ginger		
High	234	63.2
Low	90	24.3
Not at all	46	12.4
Cocoa		
High	68	18.4
Low	117	31.6
Not at all	185	50.0
Process of acquiring agricultural farm land used for cultivation		
Inherited	38	10.3
Leased	206	55.7
Purchased	84	22.7
Offered by community	42	11.4

Source of seedlings		
Farmer saved	108	29.2
Government and NGO offered seeds	25	6.8
Purchased certified seeds	185	50.0
Others (through someone)	52	14.1
Percentage of farmland used for production of agricultural commodities		
Cashew (%)		
1-20	81	21.9
21-40	54	14.6
41-60	98	26.5
Not active in this value chain	137	37.0
Ginger (%)		
1-20	89	24.1
21-40	91	24.6
41-60	34	9.2
61-80	36	9.7
81-100	40	10.8
Not active in this value chain	80	21.6
Cocoa (%)		
1-20	82	22.2
21-40	0	0.0
41-60	0	0.0
61-80	112	30.2
81-100	17	4.6
Not active in this value chain	159	43.0
Varieties of agricultural commodities planted or harvested		
Cashew		
Brazilian cashew	124	33.5
Indian cashew	62	16.8
Chinese cashew	33	8.9
Not active in this value chain	137	37.0
Both Brazilian and Indian cashew	14	3.8
Ginger		
Yellow ginger (UG 1)	103	27.8
Black ginger (UG 11)	76	20.5
Not active in this value chain	80	21.6
Both (Yellow and Black ginger)	111	30.0
Cocoa		
Forastero Amazonian	137	37.0
Criollos	30	8.1
Trinitario	44	11.9
Not active in this value chain	159	43.0
Reason for planting such varieties		
Economical	85	23.0
High demand	192	51.9
Taste preference	38	10.3
Others (Profitable)	55	14.9

Year which you supplied the highest volume of agricultural commodities						
Year	**Cashew**		**Ginger**		**Cocoa**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
2010	0	0.0	0	0.0	0	0.0
2011	0	0.0	0	0.0	0	0.0
2012	97	26.2	136	36.8	124	33.5
2013	0	0.0	0	0.0	0	0.0
2014	0	0.0	0	0.0	30	8.1
2015	0	0.0	0	0.0	0	0.0
2016	0	0.0	0	0.0	8	1.2
2017	63	17.0	0	0.0	0	0.0
2018	59	15.9	21	5.7	9	2.4
2019	0	0.0	38	10.3	0	0.0
2020	14	3.8	95	25.7	40	10.8
Average selling price (₦) per tonnes						
	Cashew		**Ginger**		**Cocoa**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
100,000-500,000	70	18.9	58	15.7	37	10.0
500,001-1,000,000	135	36.5	231	62.4	142	38.4
1,000,001-1,500,000	28	7.6	1	0.3	32	8.7
Mean	807,298.5782		582,517.2414		959,012.8755	
Years you had highest income earning from the trade of agricultural commodities						
Year	**Cashew**		**Ginger**		**Cocoa**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
2010	0	0.0	0	0.0	0	0.0
2011	0	0.0	0	0.0	0	0.0
2012	136	36.8	126	34.1	124	33.5
2013	0	0.0	0	0.0	0	0.0
2014	0	0.0	0	0.0	2	0.5
2015	0	0.0	0	0.0	0	0.0
2016	0	0.0	0	0.0	0	0.0
2017	23	6.2	0	0.0	0	0.0
2018	0	0.0	21	5.7	0	0.0
2019	21	5.7	36	9.7	0	0.0
2020	53	14.3	107	28.9	85	23.0
Factors that affect production output	**Freq.**				**%**	
Variety	14				3.8	
Weather	102				27.6	
Pest and disease	17				4.6	
Market uncertainties	178				48.1	
Input prices	59				15.9	

Source: Field data survey and SPSS computation, 2021

3.3 Cost of Production of agricultural commodities

Table 3 presents the descriptive statistics of cost of production of agricultural commodities in the study area. In terms of years which the respondents had the highest cost of production and exportation, most (40.8%, 39.8% and 34.0%) of the respondents stated that they had the highest cost of production and exportation in cashew, ginger and cocoa in the year 2012 respectively. Similarly, few (17.9%, 22.9% and 17.8%) of the respondents also specified that they had the highest cost of production and exportation in year 2020 in cashew, ginger and cocoa respectively. Furthermore, result showed that most

(42.2%, 46.0% and 31.9%) of the respondents had lowest cost of production and exportation in year 2014 in the three (cashew, ginger and cocoa) agricultural commodities. Based on the cost components, findings revealed that farming inputs (25.7%) and equipment (25.7) were the cost components that had the highest fluctuation. Moreover, land (36.2%) is the major cost component that has the highest impact followed by labour (25.4%). In addition result indicated that transportation (34.6%) is the major cost component that steadily increases among others whereas farming inputs (49.7%) steadily decrease.

TABLE 3
DESCRIPTIVE STATISTICS OF COST OF PRODUCTION OF AGRICULTURAL COMMODITIES (CASHEW, GINGER AND COCOA)

Years you had the highest cost of production and exportation						
Years	**Cashew**		**Ginger**		**Cocoa**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
2010	0	0.0	0	0.0	0	0.0
2011	0	0.0	0	0.0	0	0.0
2012	151	40.8	148	39.8	126	34.0
2013	0	0.0	0	0.0	0	0.0
2014	0	0.0	0	0.0	12	3.2
2015	0	0.0	0	0.0	0	0.0
2016	0	0.0	0	0.0	0	0.0
2017	12	3.2	0	0.0	0	0.0
2018	0	0.0	14	3.8	7	1.9
2019	4	1.1	43	11.6	0	0.0
2020	66	17.9	85	22.9	66	17.8
Years you had the lowest cost of production and exportation						
Year	**Cashew**		**Ginger**		**Cocoa**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
2010	23	6.2	51	13.7	46	12.4
2011	0	0.0	17	4.6	34	9.2
2012	0	0.0	0	0.0	0	0.0
2013	0	0.0	0	0.0	0	0.0
2014	156	42.2	171	46.0	118	31.9
2015	0	0.0	0	0.0	0	0.0
2016	42	11.4	12	3.2	0	0.0
2017	0	0.0	0	0.0	0	0.0
2018	0	0.0	39	10.5	7	1.9
2019	9	2.4	0	0.0	0	0.0
2020	3	0.8	0	0.0	6	1.6
Cost components	**Highest fluctuation Freq.(%)**		**Highest impact Freq.(%)**	**Steadily increasing Freq.(%)**	**Steadily decreasing Freq.(%)**	
Land	0(0.0)		134(36.2)	0(0.0)	50(13.5)	
Labour	45(12.2)		94(25.4)	78(21.1)	23(6.2)	
Farming inputs	95(25.7)		89(24.1)	82(22.2)	184(49.7)	
Equipment	95(25.7)		22(5.9)	42(11.4)	64(17.3)	
Transportation	93(25.1)		31(8.4)	128(34.6)	17(4.6)	
Agency services	0(0.0)		0(0.0)	17(4.6)	0(0.0)	
Trade facilitation services	42(11.4)		0(0.0)	23(6.2)	32(8.6)	

Source: Field data survey and SPSS computation, 2021

IV. DISCUSSION

Based on the results of the study, males dominated exporters of agricultural commodities in Nigeria. Also, majority of the respondents have secondary and tertiary education. This denotes that they were educated. The average experience of exportation is 6 years. This implies that respondents have being into this venture for some time and are well experienced. Findings revealed that 56% of the respondents' export cashew, 87.5% of them exports ginger while 50% of them export cocoa respectively. Most (55.7%) of the respondents leased the agricultural farm land used for cultivation of agricultural commodities. This shows that respondents have a longer period to use the land. Furthermore, results indicated that most of the respondents' source for their seedlings via purchase of certified seeds. This is because they want to obtain suitable yield after cultivation. In respect to the percentage of farmland used for production, 26.5% of the respondents use between 40-60% for cashew production, 24.6% of them use between 21-40% for ginger production while 30.2% of them use between 61-80% for cocoa production. In terms of varieties, Brazilian (33.5%) cashew; yellow and black ginger (30%) and Forastero (37%) cocoa was the most common and cultivated among the respondents. These varieties were cultivated because they are highly productive and resistant to diseases. Likewise, National Cashew Association of Nigeria (NCAN) in 2016 during their interview with Punch specified that there are incomes generating prospects in Bazilian/Indian cashew nuts. Furthermore, above half (51.9%) of the respondents indicated that the reason for planting such varieties is because of its high demand. Additionally, results show that most of the respondents (26.2%, 36.8% and 33.5%) supplied the highest volume of agricultural commodities (cashew, ginger and cocoa) in year 2012 and also earn more in the same year. This indicates the period of removal of all import duty on agricultural equipment by the federal government and likewise introduction of Growth Enhancement Support (GES) scheme during the same year. This implies that the removal of import duty and introduction of the scheme is probably beneficial to the farmers based on their export volume and earnings for that year. According to Ejiogu (2017), access to fertilizer, improved seeds and other agricultural farm inputs through GES scheme contributed to the farmers' productivity. Similarly, Tiri et al. (2014) and Nwalieji et al. (2015) opined that the contribution of GES scheme to farmers' agricultural productivity cannot be contested in Nigeria. The average selling price (₦) per tonnes of cashew, ginger and cocoa are ₦807,298.5782, ₦582,517.2414 and ₦959,012.8755 respectively. In terms of years which the respondents had the highest cost of production and exportation, most (40.8%, 39.8% and 34.0%) of the respondents specified that they had the highest cost of production and exportation in cashew, ginger and cocoa in the year 2012 respectively whereas 42.2%, 46.0% and 31.9% indicated that they had lowest cost of production and exportation in the three (cashew, ginger and cocoa) agricultural commodities in year 2014. Moreover, respondents indicated that farming inputs (25.7%) and equipment (25.7) were the cost components that had the highest fluctuation. Land (36.2%) is the major cost component that had the highest impact followed by labour (25.4%). In addition, result specified that transportation (34.6%) is the main cost component that steadily increases among others while farming inputs (49.7%) steadily decrease.

V. CONCLUSION AND RECOMMENDATION

In conclusion, agricultural farm land used for cultivation of agricultural commodities is leased while seedlings planted are source from purchase of certified seeds. Moreover, Brazilian Cashew; yellow and black Ginger and Forastero Cocoa were varieties planted due to their high demand. Result showed that the highest volume of agricultural commodities (cashew, ginger and cocoa) was produced and supplied in year 2012; and likewise earnings were more in the same year. Land is the major cost components with the highest impact while farming inputs and equipment had the highest fluctuation.

Based on the conclusion, it is recommended that more land should be allocated to the exporters of agricultural commodities so that they can expand their level of production. Similarly, they seedlings of good quality should be made available and at a reduced price. Government can provide services on trade support to aid access to global markets, thus decreasing costs of transaction and providing knowledge of trade. In addition, intensive effort should focus on creative channels of agricultural commodities in the economy of Nigeria in order to boost sustainable economic development via increased export of agricultural products.

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Implementing a Capacity Development Initiative to Build Resilience to Better Adapt to Climate Change: A Case Study in Ethiopia, Africa

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Abstract— *A five-year capacity development initiative called Small-scale and Micro Irrigation Support (SMIS) Project has been funded and launched in Ethiopia by the governments of the Netherlands and Canada in close collaboration with the local government in the year 2014. The project has been mobilized to expand the capacity of agriculture and water sectors that will use the newly-provided technologies to increase yields and quality of their agricultural products as well as to strengthen their resilience to better adapt to climate change at four Ethiopian states including the state of Tigray. The capacity building plan in the Tigray state has been implemented in eight-pilot woredas (villages) and twelve running pilot irrigation schemes. To bridge the identified capacity gaps, many regional and woreda level agriculture and water sector staff as well as the farmers have been trained using the SMIS Project six-stage capacity development strategy. The progression of several related key indicators was continuously traced using the performance measurement framework (PMF) method and the results were communicated to the stakeholders utilizing results-based management (RBM) approach. The intermittent outcomes have shown that the implementation of SMIS Project capacity development initiative has created landmark changes and outstanding qualities among the relevant institutions, staff, and farmers in the pilot schemes of all sub-regions in the Tigray state. The project has promoted more efficient institutions and was able to train many skillful farmers to build resilience to better adapt to climate change when it strikes. This paper will discuss and present the project outline and its partial achievements until the project midterm.*

Keywords— ***Adapting to climate change, building resilience, capacity development, small-scale irrigation, food security.***

I. INTRODUCTION

The compounding impact of climate change on agriculture and food production could visibly be felt in many places across Africa. The inevitable impact includes but not limited to the extreme climate events translating into massive rainfalls, devastating floods, cold snaps, heat waves, widespread wildfires, and extended droughts. Although, the occasional off-season outburst of weather anomalies is not a new phenomenon, but the recent trend of extreme weather goes far beyond the range of variances that have been commonly experienced over the course of the last several decades. Given the immense magnitude of these extreme events, there is currently no technology or applicable measures that could exclusively prevent or control these massive occurrences except for coexisting, mitigating, and building resilience to adapt.

Turral et al., (2011) have elaborated on the significance of climate variability as pointed out in the report of the International Panel on Climate Change (IPCC, 2001a and 2001b). The IPCC regularly reports the findings of its three working groups (Fig 1). The working groups investigate the physical science underlying climate change; adaptation to the impacts of climate change; and the possibilities for mitigation of greenhouse gas (GHG) emissions and global warming. According to Fig. 1, as a result of a shift in the probability of occurrence of new climate behavior (vertical axes), there is now a wider range of colder weather (blue color area on the left side of the graph) as well as a broader domain of hot weather occurrence (red color area on the right side of the curve) in many areas across the globe. The imminent significance of this variation for the world economy is less agricultural production and lower food security in the future. Cline (2007) has predicted a drop in agricultural productivity up to -5% in some places in Africa and up to -15% in Ethiopia before the year 2080 as a result of global climate change if no action is taken (Fig 2).

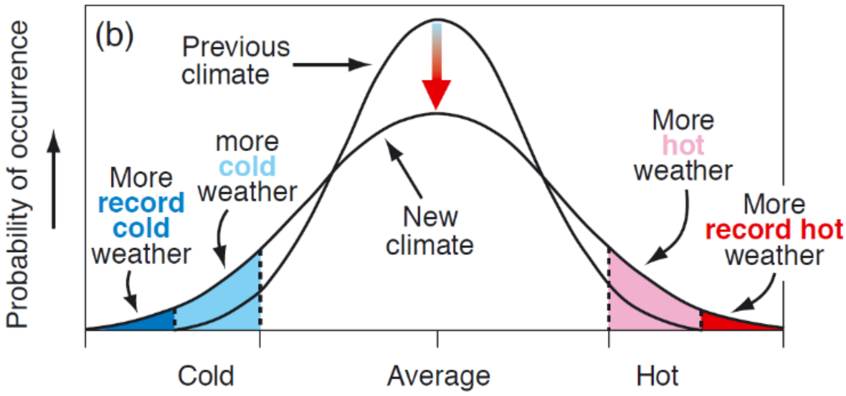

FIGURE 1: Increase in climate variance as an effect of climate change

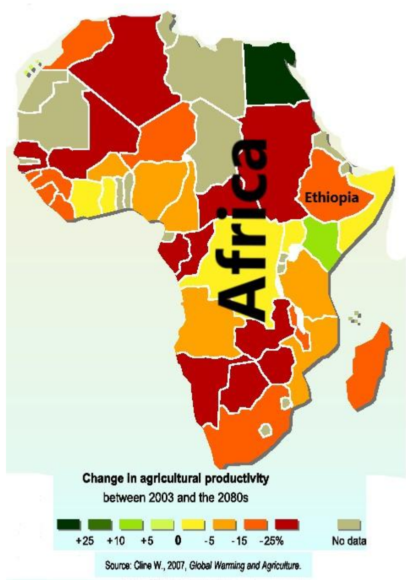

FIGURE 2. Projection of change in the agricultural productivity in Africa in 2080

Awareness and resilience on the issue of linkage between climate change and community development are well-presented and discussed by Partey et al., (2018) and Tubiello (2012). Tubiello maintains that among other factors, dealing with climate change profoundly relies on the capacity of the community of subsistence and smallholder farmers with a view to collect indigenous knowledge and enhance resilience through activities such as those aimed at improving rural livelihoods through income diversification. Turral, et al., (2011), believe that there is a need for several high impact pilot projects to improve institutional capacity for climate change adaptation. These would have to be well-resourced and long-term rather than being an imposed and short-term agenda. Accordingly, a great deal of attention should be driven to the capacity development of institutions and individuals who understand the significance of circumstance and implement the adaptation policies well in advance. Given the lack of adequate financial resources in most African countries; more innovative funding mechanisms should be developed to train and to sustain the community involvement.

The Government of Ethiopia in east Africa has given prime attention to smallholder irrigation development in the country's development agenda as a means of modernizing Ethiopia's agricultural economy and achieving food security. They have indicated that irrigation development and expansion are a major element of their Growth and Transformation Program (GTP). In October 2011, the Government of Ethiopia released the Small-Scale Irrigation Situation Analysis and Capacity Needs Assessment, which was followed shortly thereafter by the Small-Scale Irrigation Capacity Building Strategy. The intuitive action of the government of Ethiopia for generating a conducive ambience to achieve food security, on the other hand, has hastily mobilized water sector to construct numerous irrigation schemes overlooking the need for capacity development of the sector. It is believed that overstressing on physical development has propelled the regional states to pay less attention to the development of adequate technical and managerial skills to be able to develop a resilient agriculture to sustainably cope with the threats imposed by the climate change. Due to lack of adequate skills the mitigating, adapting, and recovering from climate change events has remained under-developed (Anon., 2012).

As one of the fast-growing economies in Eastern Africa, Ethiopia could be regarded as a credible recipient of capacity development programs and a role model for building a resilient agriculture to better adapt to climate change. Several policies, laws, and strategies relevant to climate change in Ethiopia include the Climate Resilient Green Economy Strategy (2011), National Adaptation Program of Action (NAPA), Ethiopian Program of Adaptation to Climate Change (EPACC) of 2011, Nationally Appropriate Mitigation Actions (NAMA) of 2010, Rural Development Policy and Strategies (2003), Growth and Transformation Plan (GTP), CAADP Compact and the National Environmental Policy of Ethiopia (1997). Ethiopia is also a signatory to several multilateral agreements that have a bearing on the sustainable development efforts of the country. Ethiopia has signed and/or ratified many of the international conventions and protocols related to climate change and land degradation including the United Nations Framework Convention on Climate Change (1994), the Convention on Biological Diversity (CBD) and the United Nations Convention to Combat Desertification (UNCCD) (Jirata et al., 2016).

Apart from international treaties, there are also several ongoing capacity development initiatives in Ethiopia (AGP, IFAD, GIZ/SLM, FAO, HELVETAS, World Vision Ethiopia, etc.); and one of these well-administered capacity development programs is Small-scale and Micro Irrigation Support (SMIS) Project that has been funded and launched by close collaboration between two foreign donors and the Government of Ethiopia (Anon., 2015a). The SMIS Project is a capacity building initiative for the purpose of the expanding capacity of local government experts, NGOs, agricultural colleges, and farmers who will use the newly-provided technologies to increase yields and quality of their agricultural products as well as to strengthen their resilience to better adapt to climate change. Building resilience for adaptation to climate change, as demonstrated in Fig 3, is profoundly linked to developing and implementing the right policies, financial input, and finally developing the capacity of institutions and individuals that is the main goal of the SMIS Project.

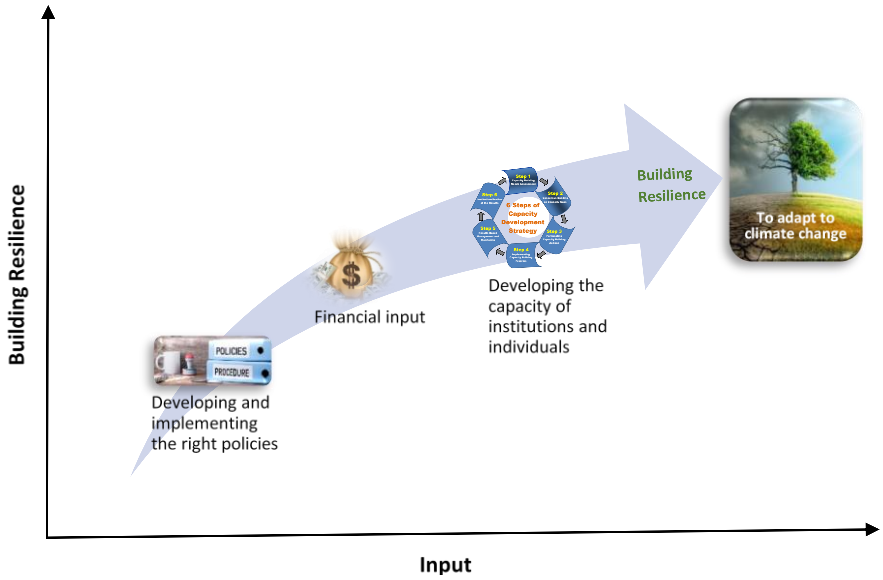

FIGURE 3: Building resilience to adapt to climate change

The SMIS Project is funded by both the governments of the Netherlands and Canada, aiming to support the Ethiopian Ministry of Agriculture and Natural Resources. With a five-year term (2014-2019), the SMIS Project includes three key components: (i) small-scale irrigation capacity development; (ii) capacity development of agricultural colleges; and, (iii) promotion of household micro-irrigation. Implementation of the project was awarded to a Canadian consulting firm (Agriteam Canada Consulting Ltd., currently known as Alinea International) through an international bid to be executed at national level as well as at four states including Amhara, Oromia, Southern Nations Nationalities and People's, and Tigray (Anon. 2015a). This paper will discuss and present the project outline and its partial achievements until the project midterm.

II. MATERIALS AND METHODS

After the SMIS Project capacity development contract was awarded to the consulting firm for implementation in November 2014, the project inception phase initiated and consultant mobilized its operational offices in the capital Addis Ababa and four pilot states. The succeeding preparatory action was to perform a capacity needs assessment survey in all four pilot states. Then, three pilot woredas (villages) and in each woreda one running pilot irrigation scheme was selected to implement the first year's capacity development program. Additional three pilot woredas and running irrigation schemes were added to the capacity development plan each year thereafter. It was intended that the selected pilot woredas and irrigation schemes being geographically diverse and serve as a close representative of other woredas and irrigation schemes among the six sub-regions of the Tigray state. The selected running pilot irrigation schemes were already funded and constructed by different international donors or the government of Ethiopia; however, they are currently managed and operated collaboratively by both Tigray Water Resources Bureau and Tigray Bureau of Agriculture and Rural Development. As demonstrated in Fig 4, by the year 2018 the number of selected pilot woredas and irrigation schemes reached at eight and twelve respectively. The results of initial capacity needs assessment survey and the subsequent first year annual work plan were presented to the local project supervisory boards in all four states as well as to the Agricultural Ministry in the capital Addis Ababa for review and approval. In addition to annual work plans, semi-annual and annual progress reports were also submitted thereafter to the project supervisory boards in the middle and at the end of each fiscal year. The annual work plans were developed in association with the partner institutions in order to integrate their annual work plans with the SMIS Project capacity development agenda and to support their projected hard and soft demands. The major component of each annual work plan includes the details of capacity development program for the upcoming year based on the principle of the capacity development strategy described as follows.

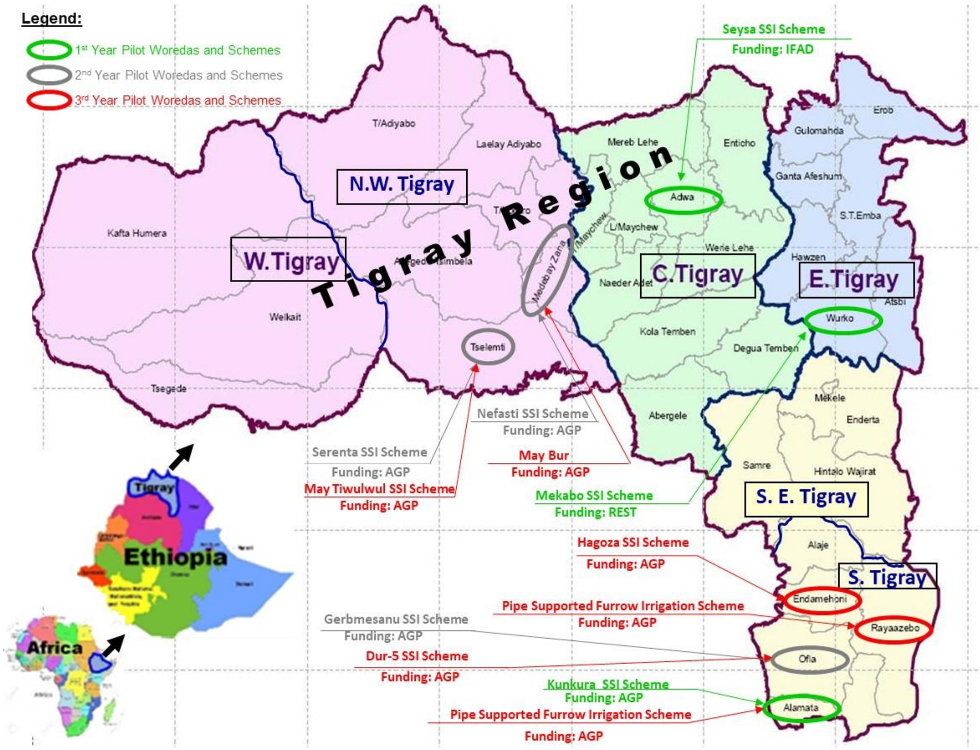

FIGURE 4: The SMIS Project selected pilot woredas and irrigation schemes in Tigray state

2.1 Capacity Development Strategy

The research on sustainable development of human capacity points to the efficacy of using a phased approach rather than a one-time event. Since the recipients of the capacity development program have mainly been the staff of various institutions and the farmers, the consultant has employed a unique facilitation technique adopted from the principles of adult learning. The approach is grounded in neuroscience, adult learning theory, and the notion that most effective learning happens on the hands-on circumstances (Anon, 2015b). Accordingly, every capacity development activity delivered in this project has been based on the state-of-the-art six-step capacity development strategy as demonstrated in Fig 5.

2.1.1 Step One: Capacity Needs Assessment

An independent field scale survey has been conducted by the staff of consultant in collaboration with the stakeholders to determine the scope of institutional and individual capacity gaps related to each of the three components of the project. The survey includes coordinating with the authorities for effective traveling to the field and performing the investigation, interviews, meetings with the local authorities, and consultation with the farmers.

2.1.2 Step Two: Consensus Building on Capacity Gaps

At the second step of capacity development strategy, the project staff has worked with the regional, zonal (not in Tigray), and woreda key stakeholders to come together to hear about the identified capacity gaps, clarify areas of agreement and disagreement, develop shared resolutions, reach consensus on obvious capacity development needs, and prioritize them to be included in the next annual work plan.

FIGURE 5: The steps of capacity development strategy

2.1.3 Step Three: Formulating Capacity Development Activities

According to the results of initial capacity needs assessment and the priorities set at the consensus building step, the initial logic model has been improved and details of activities for the first-year annual work plan has been finalized. The improved logic model formulates a guideline for preparing the future annual work plans. The capacity development activities mainly include but not limited to short-term practical training, workshops, site visits, job-embedded support, exchange visits, demonstrations, learning-by-doing, and procurement of the required hardware.

2.1.4 Step Four: Implementing the Capacity Development Program

At this step, the project staff worked with the regional, zonal (not in Tigray), and woreda experts to carry out the activities included in the annual work plan and approved by the supervisory board. The delivery of capacity development activities entails developing the competency, attitude, organizational operating structure, procedure, technology, the knowledge of individuals, and ultimately the strength of organizations to increase agricultural production and food security in order to be able to build resilience to adapt to climate change.

2.1.5 Step Five: Results-Based Management (RBM) and Monitoring

The results of implementing capacity development program have been evaluated by measuring changes in the quantity and quality of designated indicators according to the principles of performance measurement framework (PMF) and presented to the regional (state) and federal supervisory boards every six months.

2.1.6 Step Six: Institutionalization of the Results

The sixth and final step of the capacity development strategy is "institutionalization". Institutionalization is a process by which the new capacities, new skills, approaches, methods, and systems that have been successfully applied in the pilot schemes in this project to be internalized and regularized within the relevant institutions at woreda, zonal, and state level. It is also anticipated that these achievements to be cascaded to other states by the measures taken by the government of Ethiopia.

2.2 Capacity Development for Institutions

The SMIS Project was able to establish a constructive partnership with seventeen key partner institutions in the Tigray state and adopt the capacity development program according to the needs of these organizations. For instance, about 371 females and around 1,391 male engineers, technicians, and practitioners from seventeen regional institutions (1,762 in total) were trained in various subjects pointed out in Table 1. The institutional capacity development activities were designed and delivered in a very practical environment. The classroom lecture, group discussion, group presentation, field visit, and the scientific analysis of site observations were among the common practices in each training. Often senior international or national experts have been recruited to serve as facilitator or resource expert to enrich the event through sharing their expertise with the trainees. The training topics were initially derived from the initial capacity needs assessment survey during the inception phase and then evolved over the course of further regional interactions with the stakeholders. The Tigray Bureau of Agriculture and Rural Development ranked first in receiving the capacity development training (466 staff trained for 182 days) and Tigray Water Resources Bureau marked the second (366 staff trained for 177 days) followed by NGOs and agricultural college during 2015-2018 period. Some capacity development activities were repeated several times according to the demand of relevant institutions as the time allowed.

TABLE 1
THE NUMBER OF STAFF TRAINED FROM VARIOUS INSTITUTIONS IN TIGRAY (2015-2018)

No.	Participating Local Institution	Number of Trainees			No. of days Trained
		Male	Female	Total	
1	Tigray Bureau of Agriculture and Rural Development	393	73	466	182
2	Tigray Water Resources Bureau	309	57	366	177
3	Relief Society of Tigray	60	1	61	112
4	Tigray Water Works Study, Design & Supervision Enterprise	45	4	49	56
5	Tigray Agricultural Research Institute	6	0	6	1
6	Mekele University	3	2	5	4
7	Bureau of Women's Affairs	15	10	25	25
8	Cooperative Promotion Agency	29	5	34	24
9	Wukro Agriculture Technical and Vocational Educatiion and Training	45	6	51	51.5
10	Tigray Environmental Protection, Land use & Administration Agency	4	0	4	9
11	Agricultural Transformation Agency	1	0	1	1
12	Agricultural Growth Program	30	4	34	51
13	International Fund for Agriculture Development	3	0	3	6
14	Sustainable Land Management Program (GIZ/SLMP)	0	0	0	0
15	HELVETAS	1	0	1	1
16	Bureau of Planning and Finance	50	9	59	25
17	Various Private Sectors	397	200	597	50
	Total	1,391	371	1,762	-

The capacity development programs were spearheaded to supplement the knowledge of the participants and strengthen their skills to better perform their tasks and to enhance institutional resilience to be able to better adapt to the adverse impact of climate change when it strikes. According to the initial capacity needs assessment in other states, a similar capacity development effort has been formulated and delivered to the local institutions in other three pilot states by the SMIS Project. Table 2 shows the list of provided key capacity development topics for various institutions in the state of Tigray.

TABLE 2
THE LIST OF KEY CAPACITY DEVELOPMENT TOPICS FOR INSTITUTIONS IN TIGRAY (2015-2018)

No.	Capacity Development Topic	Main Participants	Presented	Building Resilience for Adapting to Climate Change
1	Facilitation skills	All relevant institutions and NGO's	Twice	Strengthened target institutions to better manage the climate change challenges
2	Policies	All relevant institutions and NGO's	Once	Created awareness within the target institutions about organizational tasks and responsibilities related to agriculture and water
3	Project management	Water Sector and NGO's	Twice	Strengthened target institutions to better manage the climate changes crisis when it strikes
4	Contract Administration	Water Sector and NGO's	Twice	Empowered target institutions to better administer multiple actors when climate change hits
5	Integrated watershed management	Water, Agriculture and Environment Sectors	Once	Reinforced target institutions to prevent degradation of natural resources that leads to worsening the adverse impact of climate change
6	Water balance and water allocation	Water Sector and NGO's	Once	Strengthened target institutions to better manage water resources to reduce vulnerability of communities to adverse impact of climate change
7	Design of small dams	Water Sector and NGO's	Once	Supported target institutions to better manage water resources to reduce shocks generated from climate change
8	Design of irrigation infrastructure	Water Sector and NGO's	Once	Reinforced target institutions to better utilize water to lessen the impact of climate change
9	Design and maintenance of check dams	Water Sector and NGO's	Once	Strengthened target institutions to better use their resources to diffuse the adverse impact of climate change
10	Asset and financial management	Water Sector, Agriculture Sector and NGO's	Once	Supported target institutions to better maintain and exploit their hard and soft resources to control the adverse impact of climate change
11	Water user associations	Water Sector and NGO's	Several times	Empowered target institutions to better organize farmers to collaboratively tackle the adverse impact of climate change
12	Monitoring and Evaluation	All relevant institutions and NGO's	Several times	Offered training to target institutions to understand the basis of results-based management (RBM) as well as performance measuring framework (PMF) to better monitor and report their achievements to be able to highlight their deficiencies and make fast track decisions to fight against the adverse impact of climate change when needed.
13	Computer and Laboratory skills	Agricultural college	Once	Provided hardware and soft resources to upgrade the skills and resilience of instructors to better manage the adverse impact of climate change
14	Job embedded support	Agriculture and Water Sectors	Several times	Supported target institutions to better prepare and implement the new set of learned skills
15	Site visits	All relevant institutions and NGO's	Several times	Mobilized target institutions to gain practical experience about the new set of learned skills
16	Abroad study tour	Agriculture and Water Sectors	Once	Supported target institutions to gain high level experience about the new set of learned skills

Fig 6 shows pictures from classroom lecture and field activities in the Tigray state during the period of 2015-2018.

FIGURE 6: Institutional capacity development training in the state of Tigray

2.3 Capacity Development for Individuals (end users)

The capacity development activities for individuals incurred slight changes from the institutional capacity development program to capture the farmers' demands. The activities include but not limited to the classroom review of the basics, group discussion, group presentation, site visit, on-site demonstration, and on-site hands-on practices. Often senior local experts from relevant institutions served as facilitator or resource expert. The capacity development topics were initially derived from the first capacity needs assessment survey during the inception phase and evolved during the subsequent mutual interactions. All capacity development activities were delivered directly to the farmers and other end users on their own farms. Some capacity development activities were repeated several times based on the availability of farmers. The capacity development topics were directed to add to the knowledge of the participants and strengthen their skills to build further resilience to be able to adapt to the adverse impact of climate change. According to the capacity needs assessment in the other three states, a similar capacity development effort has been formulated and delivered to the farmers of the pilot woredas (villages) by SMIS project. Table 3 shows the list of provided key capacity development topics in Tigray during 2015-2018.

The capacity development activities in the Tigray state were delivered to some selected pilot farms in the designated woredas (villages); however, in each activity at least a representative from the relevant institutions were also present to be able to collect the materials for further cascading the training to the farms in other woredas. Fig. 7 displays pictures from field activities during delivering some of the capacity development practices in Tigray (2015-2018).

TABLE 3
THE LIST OF KEY CAPACITY DEVELOPMENT TOPICS FOR INDIVIDUALS IN TIGRAY (2015-2018)

No.	Capacity Development Topic	Main Participants	Presented	Building Resilience for Adapting to Climate Change
1	Micro-irrigation	Farmers	Several times	Educated farmers to use the simple and efficient irrigation techniques to conserve water and to build resilience against the adverse impact of climate change
2	On farm water management	Farmers	Several times	Trained farmers to better manage water on their farms to increase the water use efficiency and to build resilience against the adverse impact of climate change
3	Pump training	Farmers	Several times	Provided pump repair skills to eliminate the waste of time and financial burden for farmers to be able to minimize the adverse impact of climate change
4	Roof and catchment water harvesting	Farmers	Once	Educated farmers to store water to reduce water stressed induced by the adverse impact of climate change
5	Participatory irrigation development management	Farmers	Several times	Offered guidance to the farmers how to systematically share their ideas and concerns in order to enhance irrigation performance to be able to lessen the adverse impact of climate change
6	Agronomy and IPM	Farmers	Several times	Provided training to the farmers to apply IPM approach to increase food safety and to minimize vulnerability against the adverse impact of climate change
7	Crop diversification	Farmers	Several times	Presented workshop to the cluster of farmers to introduce new nutritional crops to increase food security and to reduce the vulnerability against the adverse impact of climate change
8	Extension services	Farmers	Several times	Provided training and workshops to the farmers to demonstrate the provision of good care to crops to increase food production and to minimize vulnerability of communities against the adverse impact of climate change
9	Gender main streaming	All relevant institutions, NGO's and farmers	Several times	Educated participants about gender equity to reduce the cultural barriers to support agriculture and food production to encounter the adverse impact of climate change
10	Exchange visits	All relevant institutions, NGO's and farmers	Several times	Provided facilitation so that the participants visit other successful farms and producers to learn and improve the quantity and quality of their products to decline the vulnerability the adverse impact of climate change

III. RESULTS AND DISCUSSIONS

The SMIS capacity development initiative was run in four pilot states in Ethiopia; however, only the results of capacity development in the Tigray state and only until the midterm review (about three and half years out of five years) is presented and discussed in this paper. The project employs results-based management (RBM) approach to communicate the achievements using the performance measurement framework (PMF) to show the project intermittent outcomes. The midterm review includes performance evaluation of some selected quantifiable and nonquantifiable indicators against baselines. The project performance indicators were already included in the initial project request for proposal (RFP) and then transferred to the consultant's contract as an assessment criterion. The data for assessment of intermittent outcome have been collected through a credible document review, farm survey, and independent interview by monitoring and evaluation experts using government of Ethiopia document and irrigation water user association reports (Anon., 2018). Table 4 displays and compares the status of baseline at the beginning of the project versus the achieved key intermittent outcomes until the midterm review (2015-2018) in the Tigray state. The key intermittent outcomes include developing many standard procedures, adopting efficient management of irrigated agriculture, expansion of cultivation of high value and market-oriented crops, more water user associations successfully taken over the O&M responsibility, increase in yield for selected crops (potato, onion, tomato, pepper & head cabbage), hundreds of farms utilizing micro-irrigation. The level of resilience built as a result of implementation of SMIS Project capacity development initiative has also been hypothetically analyzed based upon the notion that the project has significantly strengthened the institutions and individuals in the field of irrigated agriculture and food security at woreda and regional level thus ensuring an increased level of resilience to better adapt and mitigate the adverse impact of climate change.

FIGURE 7: Capacity development training for individuals (end users) in the state of Tigray

TABLE 4
SOME ACHIEVED KEY INTERMITTENT OUTCOMES IN TIGRAY STATE (2015-2018)

<table>
<tr><th>No.</th><th>Indicators</th><th>Baseline</th><th>Achieved</th><th>Building resilience for adapting to climate change</th></tr>
<tr><td>1</td><td>Standardized procedures for small scare irrigation and micro-irrigation planning, design, construction, supervision and monitoring</td><td>Poor</td><td>Improved</td><td rowspan="9">Strengthened institutions and individuals in the field of irrigated agriculture and food security at woreda and regional level thus ensuring an increased degree of resilience to better adapt and mitigate the adverse impact of climate change when needed.</td></tr>
<tr><td>2</td><td>Level of access to better planning and efficient management of irrigated agriculture</td><td>Poor (1/5)</td><td>Fair (3/5)</td></tr>
<tr><td>3</td><td>% of pilot schemes where 80% of designed command area is actually irrigated.</td><td>30%</td><td>90 %</td></tr>
<tr><td>4</td><td>% of pilot schemes with at least 15% of irrigated area used for cultivation of high value and market-oriented crops</td><td>50 %</td><td>80 %</td></tr>
<tr><td>5</td><td>% of pilot schemes where irrigation water user associations have successfully taken over the O&M responsibility</td><td>50 %</td><td>90 %</td></tr>
<tr><td>6</td><td>% increase in yield for selected crops (potato, onion, tomato, pepper & head cabbage)</td><td>Male House Hold =78qt/ha
Male House Hold =60qt/ha</td><td>20 % increase</td></tr>
<tr><td>7</td><td>% of water users (male/female) provided with new/improved irrigation services</td><td>0</td><td>9600</td></tr>
<tr><td>8</td><td>% of farms utilizing micro-irrigation</td><td>0</td><td>800</td></tr>
<tr><td>9</td><td>Center of Excellence for Irrigation Water Management operational</td><td>0</td><td>100%</td></tr>
</table>

For instance, the trainings that were offered in integrated watershed management, irrigation infrastructure design, check dams, roof water harvesting, and water balance and water allocation (Table 2) were among the programs that have fundamentally capacitated the partner institutions to build adequate resilience in their institutions to better adapt to climate change. Also, the micro-irrigation, pump training, agronomy and IPM, crop diversification, and gender mainstreaming workshops presented to the cluster of farmers have profoundly strengthened the farmers to build stronger resilience in their community to easier and faster adapt to climate change.

IV. SUMMARY AND CONCLUSION

Many irrigation schemes have been constructed in Ethiopia since the 1980s; however, the continued desire of the government of Ethiopia to reach to a sustainable level of food security is still far-fetched. Often either due to improper utilization of irrigation infrastructure or because of lack of adequate skills the agricultural productivity is very low. Therefore, capacitating the staff of relevant institutions as well as the farmers are recognized as one of the key steps in filling the existing gaps and even transforming rain-fed agriculture to irrigated agriculture. To fill this pandemic gap, some of the regional and woreda agricultural staff, as well as the farmers in some selected pilot schemes, have been trained using the SMIS Project six-stage capacity development strategy. The intermittent outcomes have demonstrated that the implementation of SMIS Project capacity development initiative has created landmark changes and outstanding qualities among the relevant institutions and farmers in the pilot schemes of the state of Tigray. The project has created more efficient institutions and additional skillful farmers to build resilience to adapt to climate change when it strikes.

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