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LEVEL OF PREPAREDNESS FOR BIOTECHNOLOGY: A CASE STUDY OF SIAYA INSTITUTE OF TECHNOLOGY IN SIAYA COUNTY KENYA

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Abstract

Biotechnology harnesses cellular processes to develop technologies and products that help improve healthcare, agriculture, non-food industrial production and environmental sanitation. These processes and products of Biotechnology are a global utility and hence there is need to align TVET training to the global skills needs. Biotechnology training in TVET institutions is challenged by inadequate training infrastructure in TVET institutions and low capacity building among TVET trainers. This study mainly assessed the level of preparedness of TVET institutions for biotechnology with a special focus on biotechnology infrastructure, trainer qualifications and government policy formulations in Siaya Institute of Technology. Using questionnaires, observations, oral interviews and secondary data, a descriptive research survey in Applied Sciences Department (AS) and Agriculture Departments (AD) showed 2 (16%) capability built staff in AS and 1 (10%) in AD. Pleasantly, 88% (16/18) of the equipment required in a biotechnology laboratory were available for training and practice. In both AS and AD, the trainers showed 99% acceptance to practicing biotechnology. Notably, favorable government policies were already an impetus to biotechnology practice in Kenya. For instance, developed Occupational standard and Curricula for Biotechnology from TVET-CDACC Kenya, have given an enabling platform. The National Biosafety Act, 2009, had been established to regulate the practice of biotechnology and to ensure human and animal health. Descriptive statistics was used in SPSS to analyze data on trainer qualifications and equipment availability. There is need to enhance capacity building, improve biotechnology infrastructure in TVET institutions and introduce biotechnology as a course in TVET institutions to achieve Kenya's vision 2030 and the world's SDGs.

Key words: Preparedness, biotechnology, infrastructure, staff training, government policies, TVET institutions

INTRODUCTION

The Cartegena Protocol, (2000) defines biotechnology as any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or process for a specific use.

Brewing and baking bread are examples of processes that fall within the concept of biotechnology. Today, biotechnology covers many different disciplines such as genetics, biochemistry, molecular biology and tissue culture. New technologies and products are developed every year within the areas such as medicine (therapeutics and therapies), agriculture (development of genetically modified plants, biofuels, and biological treatment) or industrial biotechnology (production of chemicals, paper, textiles, alcoholic beverages, milk products and other food (NTNU, 2020).

The main branches of biotechnology include animal biotechnology, medical biotechnology, industrial biotechnology, environmental biotechnology, plant biotechnology. These branches of biotechnology mainly point at the fundamental areas of application. The key areas of application are highlighted below.

Environmental Biotechnology deals with detoxification of waste and industrial effluents, treatment of sewage water and control of plant diseases and insects through the use of biological agents such as viruses, bacteria and fungi. It simply entails the conversion of organic wastes, environmental bioremediation of harzardous contaminants, environmental protection and monitoring (Maria and Violeta, 2013 and Gavrilescu, 2010).

Environmental bioremediation is the process of reducing or eliminating pollutants in the environment through the application of biotechnology in the form of biotreatment. According to Gavrilescu (2010), biotreatment/ bioremediation methods are applied to remove, degrade or detoxify pollution in environmental media such as water, soil, air, and wastes. Microbes such as yeasts, fungi, protozoa, unicellular plants, rotifers and bacteria are used in bioremediation process because most of them have the potential to degrade most hazardous and recalcitrant chemical pollutants in the environment.

Plant biotechnology is a combination of tissue culture and genetic engineering. It deals with development of transgenic plants with resistance to biotic and abiotic stresses; development of haploids, embryo rescue, clonal multiplication, cryopreservation, and somatic hybridization (Thieman, 2008).

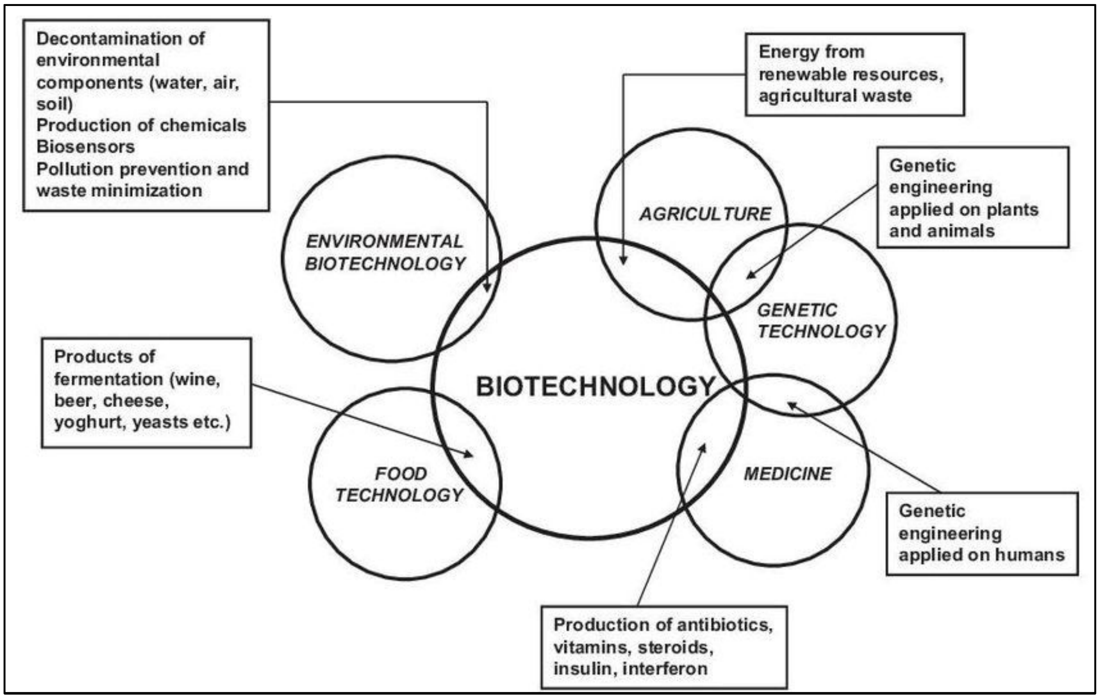

Figure 1. Applications of biotechnology.Source: Sukumaran, (2006) and Gavrilescu, (2010)

The application of biotechnology in tissue culture has offered tremendous benefits. Seedless plants mainly cassava, pineapples, napier grass, potatoes, sugarcane, bananas, sweet potaties, irish potatoes and yams are regenerated and proliferated from explants in large numbers to any desired population of plants within a shorter period of time than in vegetative propagation. Moreover, the plants are highly productive, disease-free and fast maturing. The process of tissue culture is illustrated in Figure 2.

Figure 2. Regeneration of plants from plantains Embryogenic Cell suspension (ECS). Source: Onyango et al., 2016).

Plant genetic engineering offers myriads of benefits that include and not limited to resistance to biotic and abiotic stress conditions, high productivity and nutrient supplementation in plants. The process of genetic engineering is illustrated in Figure 3.

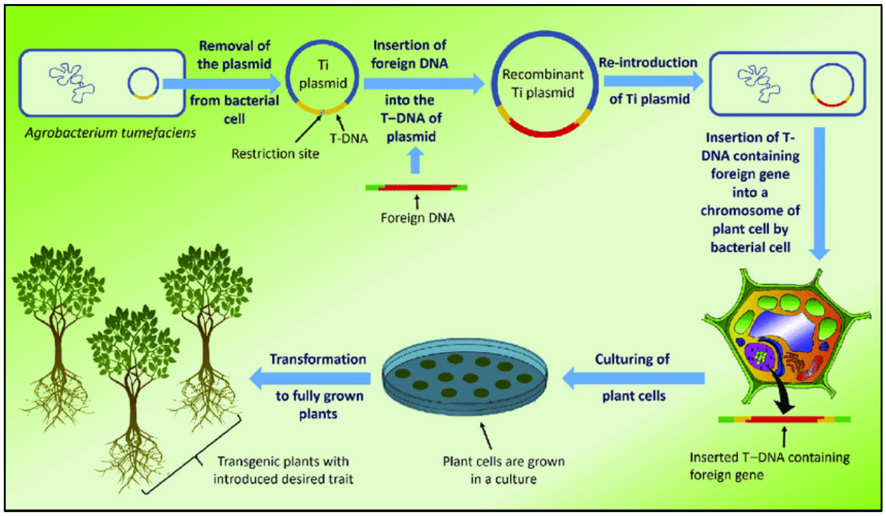

Figure 3. Plant transformation with a foreign desired gene from another plant or organism. https://www.researchgate.net/figure/Scheme-for-plant-transformation-through-Agrobacterium-method

Industrial Biotechnology deals with commercial production of various useful organic substances such as acetic acid, citric acid, acetone, glycerine and antibiotics like penicillin, streptomycin, mitomycin through the use of microorganisms especially fungi and bacteria (Thieman,2008).

Applications of biotechnology in food processing include fermentation bioprocess, the use of food additives and processing aids used in food formulations. Such products are enzymes,amino acids, vitamins, organic acids, certain carbohydrates and flavouring agents produced using genetically modified micro-organism as highlighted by FAO, 2010 and Jasia *et. al.*, (2017).

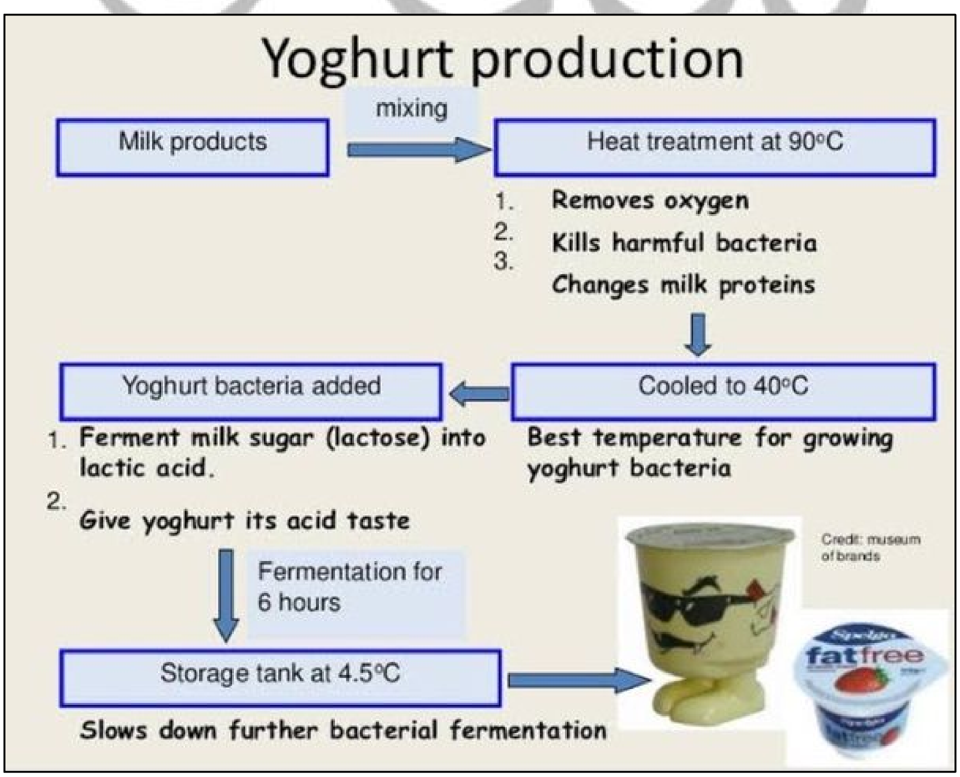

Figure 4. Yoghurt production from *Lactobacillus bulgaricus* and *Streptococcus thermophile:* https://www.google.com/search?q=production+of+yoghurt+from+bacteria&tbm

Biotechnology's has potential contribution to global wood supply and forest conservation. Forestry today is on the threshold of the widespread introduction of biotechnology into its operational practices. In many cases, the biotechnology likely to be introduced is simply an extension of that being utilized in agriculture, such as herbicide-tolerant genes. However, biotechnology in forestry also is developing applications unique to forestry, including genes for fiber modification, lignin reduction and extraction, and for the promotion of straight stems and reduced branching.

Animal biotechnology deals with development of transgenic animals for improvement of genetic traits such as resistance to various diseases. It also deals with in vitro fertilization and transfer of embryo in animals including man (Thieman, 2008).

There are many potential applications of transgenic methodology to develop new and improved strains of livestock. Practical applications of transgenics in livestock production include enhanced prolificacy and reproductive performance, increased feed utilization and growth rate, improved carcass composition, improved milk production and/or composition, modification of hair or fiber, and increased disease resistance. Development of transgenic farm animals allows more flexibility in direct genetic manipulation of livestock (Wheeler, 2013). Animal transgenic technology is illustrated in Figure 6.

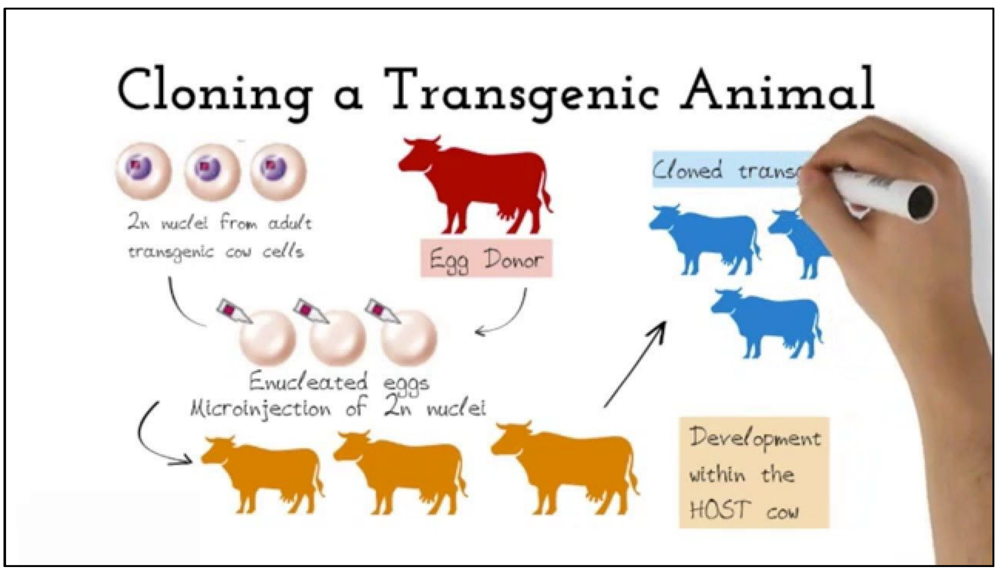

Figure 5. Production and cloning of a transgenic animal for improvement of genetic traits from a desired animal. https://www.google.com/search?q=Transgenic+animals+images.

Medical Biotechnology deals with diagnosis of various diseases, large scale production of various drugs and hormones such as human insulin and interferon, vaccines for chicken pox, rabies, polio; and growth hormones. In the field of medical science, genetic engineering has helped in the large scale production of hormones, blood serum proteins; in the development of antibiotics, and other medically useful products (Thieman,2008).

Gene therapy is used to treat genetic disorders usually by the insertion of a normal gene or correct gene for the defective or inactive gene into an individual with the help of vectors such as retrovirus, adenovirus, and herpes simplex virus. The normal gene replaces the defective or inactive gene and carries out its functions. The therapy has the highest chances of developing a permanent cure if introduced in the earliest stages of life.

To produce recombinant insulin, the specific gene sequence that codes for human insulin is introduced in *E.coli* bacteria. The gene sequence alters the genetic composition of the *E.coli* cells. Within 24 hours several *E.coli* bacteria containing the recombinant human insulin gene are produced. The recombinant human insulin is isolated from *E.coli* cells, purified and package for consumption. This technique is illustrated in Figure 7.

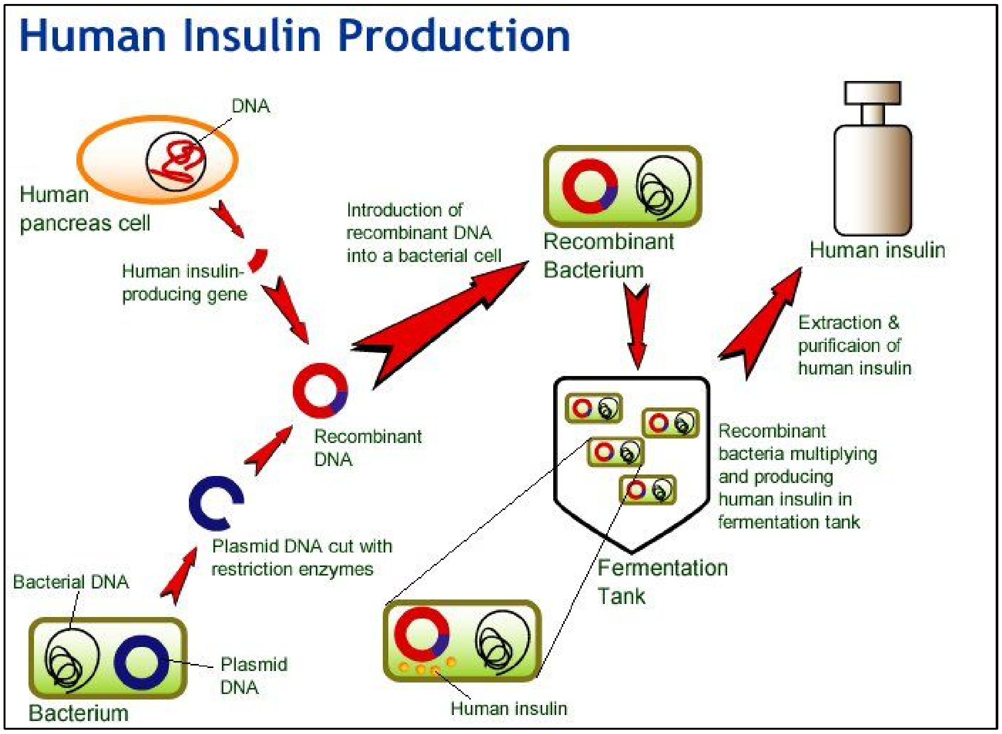

Figure 6. Production of insulin using human insulin producing gene in recombinant bacteria.https:// www.google.com/search?q=Insulin+production&tbm=isch&ved

Medical diagnosis is another application of biotechnology in the health sector. This can be achieved with the help of techniques such as Recombinant DNA Technology, Polymerase Chain Reaction (PCR) and Enzyme-Linked Immunosorbent Assay (ELISA), and Rapid Diagnostic Tests (RDTs). The Gold Standard for diagnosis of Covid-19 is the use of Real Time–PCR (RT-PCR) and yet this technology is only available in research stations and a few Kenyan universities.

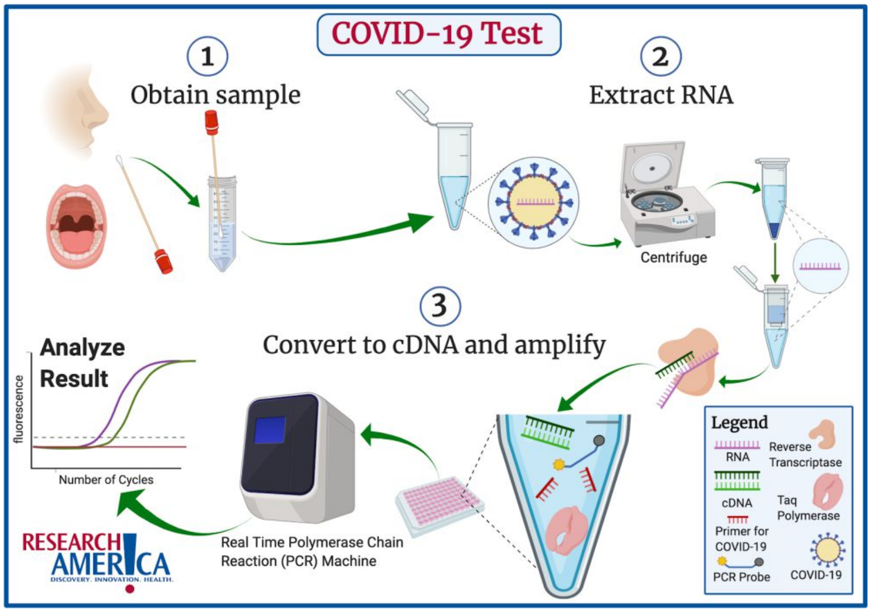

Figure 7. Diagnosis of Covid-19 by RT-PCR. .https://www.google.com/search?q= Diagnosis +softcovid-19+images. (Ackerman and Eisenburg, 2020).

In Kenya, food consumption is outpacing food production. According to New Institute for Security Studies report, annual agricultural production will need to increase by an estimated 75% from 2015 levels in order to meet consumption in 2030. The need for Agricultural Biotechnology to bridge the gap in Kenya is long overdue. The low pace of Biotechnology has not only lowered Agricultural production, but has also contributed to a decline in industrial growth in the country. Kenya depends largely on developed nations for imports on Biotechnology products ranging from textiles, therapeutics, diagnostic kits and food stuffs.

Despite the wide spectrum of applications of Biotechnology in any economy in the world, training in biotechnology in TVET institutions has been hampered by myriads of factors. The key barriers are mainly poor infrastructure, lack of trained personnel in biotechnology and non-emphatic government policies. To achieve the Kenya's vision 2030 and the worlds SDGs, there is need for capacity building and provision of infrastructure for training biotechnology in the TVET sector. The TVET sector plays a key role in industrial growth and shall therefore be at the forefront in introduction of Biotechnology.

METHODOLOGY

The research design adopted for the study was descriptive survey. The descriptive survey design was used because the study sourced data from a sample of trainers of Siaya Institute of Technology. A two–stage clustered sampling technique was used. Out of 22 trainers in Applied Sciences and Agriculture Departments, only 12 trainers who specialize in either Agriculture and/or Biology were recruited for the survey due to their legibility for professional development in Biotechnology. The study was conducted during the month of April 2020.

Structured questionnaires, observations and interviews and secondary data were used for data collection. The validity of the data collection tool was verified by Research and Development Department of S.I.T. All the information gathered from the study using the questionnaires were checked for accuracy, clarity of expression. Data was analyzed using descriptive statistics in SPSS version 21.0 and presented descriptively using tables, frequencies and percentages. The results of the findings were interpreted appropriately.

RESULTS AND DISCUSSIONS

Assessment of trainer qualifications

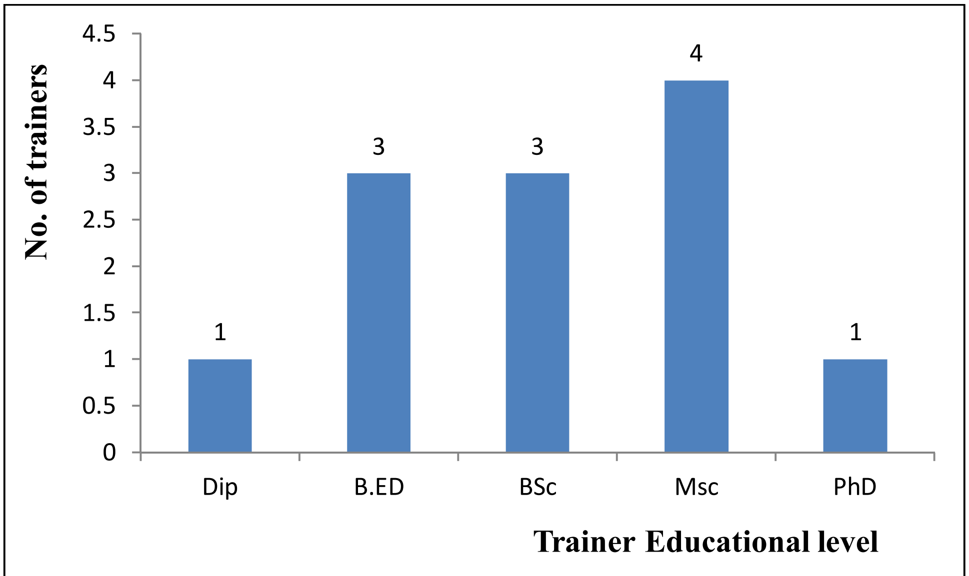

Figure 8. Trainer Education levels in Applied Sciences and Agriculture Departments

The results in Figure 8 reveal a highly competent staff in the departments of Applied Sciences and Agriculture Departments. From the results, 1(8.3%) staff has Diploma qualification, 3(25%) have B.Ed Science qualifications, 3(25%) have B.Sc qualifications, 4(33.3%) have Msc. qualifications and 1(8.3%) has a PhD qualification. This educational achievements provide a conduscive atmosphere for good policy formaulations for a new curriculum implementation. In addition, researches have also shown that the ability of teachers to implement the curriculum is dependent on variables such as teacher qualification (Snyder et al., 1992; Vaughn et al., 2000). The professional qualifications play a crucial role since curriculum implementation requires a knowledgeable and highly skilled staff.

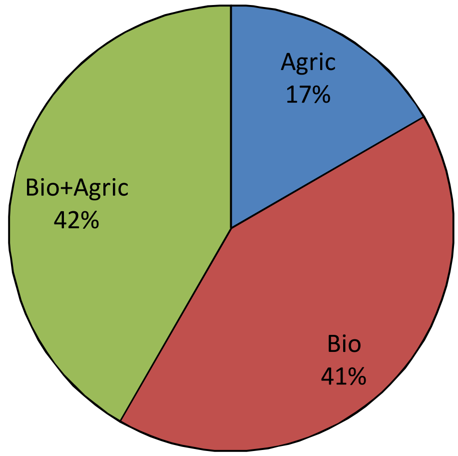

Figure 9. Trainer areas of specialization defining legibility to train in biotechnology

Notably, the results in Figure 9 show that all the 12(100%) of the staff recruited for the survey had ether Biology and/or Agriculture competencies. The training disciplines are closely related to the field of Biotechnology. This can easily pave way for professional development to specialize in Biotechnology too. Out of the 22 trainers found in both AS and AD, 12(55%) were experienced in biology and/or Agriculture with at least a first degree. Owusu and Yiboe, (2013) in their research reveal that teacher experience is a good predictor of a successful curriculum implementation. The success of implementation of Biotechnology will be made possible by vast experience of many of trainers in disciplines which share many concepts with Biotechnology such as Biology and Agriculture.

Table 1: Competencies required in training Biotechnology

Area of Competency	Frequency (n=12)	Percentage (%)
Molecular Biology	2	16.3
Biochemistry	1	8.3
Plant breeding	1	8.3
Tissue culture	1	8.3

Biotechnology applies basic biological sciences such as molecular biology, biochemistry, cell biology, embryology, genetics, microbiology and conversely provides methods to support and perform basic research in biology. The key competencies required for one to qualify to be a trainer in biotechnology (Table 2) were found to be existent in the two departments. One (8.3%) had Bsc. Biochemistry while 1(8.3%) had trained in plant breeding with the capability to practice and guide trainees. Only 2(16.3%) of the staff had adequately trained in molecular biology techniques and are fully competent to train Biotechnology. Of the two, one trainer had Msc. Biotechnology and long-term industrial experience in both molecular biology and tissue culture techniques.

Table 2: In-service courses attended by trainers since 2017-2020

In-service course attended	Frequency	Percentage (%)
Competency Based Assessment	12	100
Monitoring and Evaluation	1	8.3
Molecular Biology	2	16.7
Food Security	2	16.7
Agronomy	1	8.3
Biochemistry	1	8.3
Strategic management	1	8.3

The in-service courses (Table 2) attended by staff in the department, though play a vital role in effective curriculum implementation in the disciplines, have not focused on professional development in Biotechnology. However, CBA training which has achieved a 12(100%) staff training will be a perquisite in training Biotechnology too. Two (16.7%) have trained in both molecular biology and food security which point towards an inclination to advancing biotechnology competencies. It is generally believed that with the implementation of certain in-service training programmes the performance of teachers regarding their professional skills, knowledge and experience can be significantly improved (Junejo et a., 2017). In order to improve the probability of introducing Biotechnology in the TVET sector, there is need to conduct in-service courses in the training areas in Biotechnology (Table 1).

Assessing the Availability of Training infrastructure

Laboratory

Siaya Institute of Technology has two well-structured Science Laboratories with all functional sections. There is no doubt that the laboratories can accommodate training and practice of Agricultural Biotechnology and DNA analysis to begin with. However, to practice Agricultural Biotechnology, a growth room and a tissue culture room shall be incorporated and fitted with self-locking doors and air-conditioners to avoid contamination of tissue cultured plantlets.

The key areas to consider when setting up a biotechnology teaching laboratory are: office spaces, tissue culture room, wash room, chemical and equipment storage, growth room, working benches and changing room as illustrated in Figure 11 (Daugherty, 2017). These sections are part-and-parcel of the Science laboratory in S.I.T.

A greenhouse is used for acclimatization of plants from a tissue culture laboratory. It is established alongside a biotechnology laboratory to allow for hardening of plants before transfer into the field for crop production. There will be need of establishing a greenhouse before the onset of practice and training of Biotechnology in Siaya Institute of Technology.

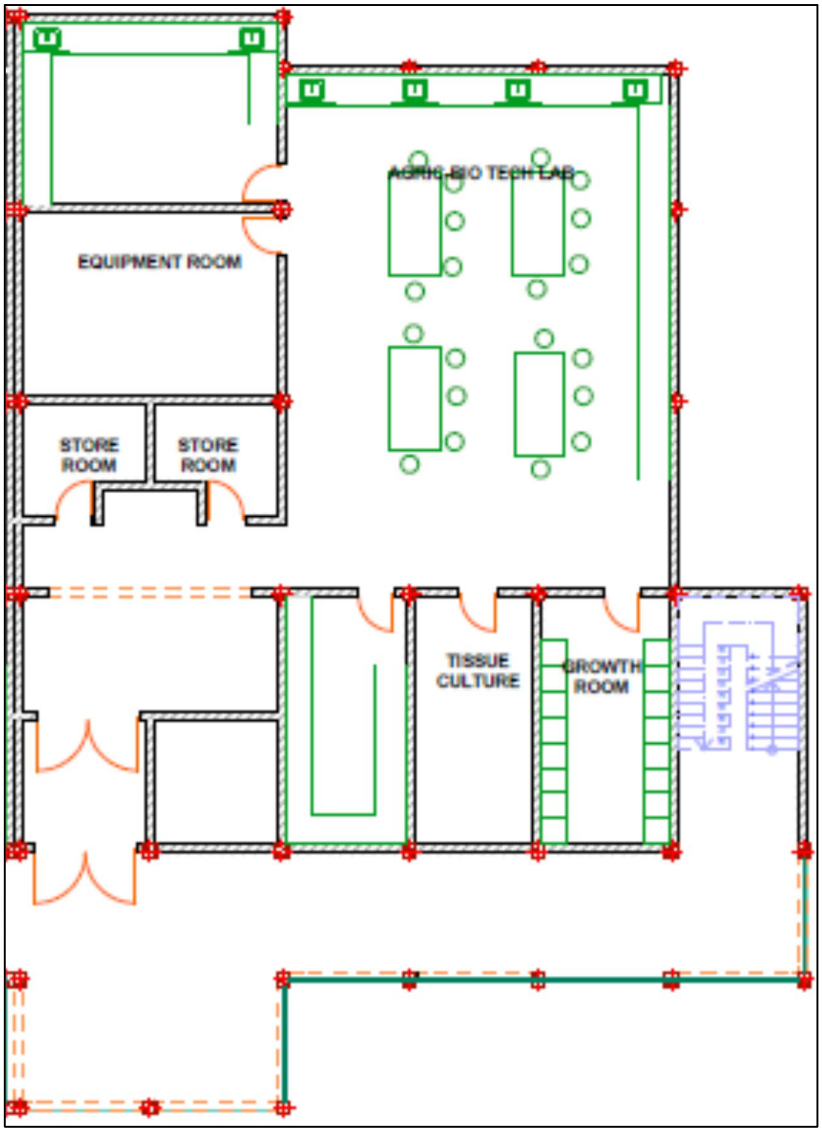

Figure 10. A Portion of Architectural Drawing of a Biotechnology Laboratory drawn in the year 2018 by Bob Nyakech, a trainer of Building and Civil Engineering Department, Siaya Institute of Technology.

Tools and equipment in a Biotechnology Laboratory

During training in the Biotechnology program, a trainee learns to use, calibrate and troubleshoot many pieces of equipment used in biotechnology laboratories and make a variety of reagents. A trainee is required to keep a list of the equipment he/she learns to use and a brief description of the purpose of the machine. For example, a PCR machine is used to amplify a specific section of DNA. According to Fletcher et al., 2011, a biotechnology laboratory should have the following tools and equipment to be functional:

Table 3: Basic Tools and Equipment in a Biotechnology Laboratory

Activity	Specific Tools/Equipment	Availability
Measurement of Volume	Erlenmeyer flasks	AV
	Beakers	AV
	Graduated cylinders	AV
	Volumetric flasks	AV
Measurement of Weight	Mechanical balances	AV
	Electronic balances	AV
Measurement of pH	A pH meter	AV
Measurement of light	Spectrophotometer	AV
Solution Preparation	Magnetic stirrers	AV
	A vortex mixer	AV
Microbiological techniques	Autoclaves	AV
	A biological safety/cell culture hood	AV
	Fermenters	NA
	Light/Bright field microscopes	AV
Preparation of biological samples for analysis		
	A micro centrifuge	AV
Separation of macromolecules	Submarine gel electrophoresis system	NA
Manipulation of Nucleic Acids	A thermal cycler	AV
	DNA trans illuminator	AV

Note: "AV" means Available while "NA" means Not Available in the laboratory at Siaya Institute of Technology.

Out of the 20 categories of tools and equipment required in a biotechnology laboratory, through observation, it was reported that only two categories were not available in the laboratory to allow for the practice and training. There is need for the government to prioritize the implementation of biotechnology to allow for easy funding and procurement of tools and equipment urgently required. An assessment of the existent tools and equipment in the laboratory revealed 16/18 (88%) probability to adopt Biotechnology.

Assessing the Effect of Policy Formulations on Implementation of Biotechnology

Curriculum Development

The Kenyan Curriculum Development, Assessment and Certification Council (CDACC) has developed curricular and Occupational Standards (OS) for levels 5 and Levels 6 for curriculum implementation of Biotechnology in TVET institutions in Kenya (TVET CDACC, 2019). These curricular and OSs include:

1. TVET CDACC, (2019). National Occupational Standards For Biotechnician Levels 5, 2019
2. TVET CDACC, (2019). National Occupational Standards For Biotechnician Levels 6, 2019
3. TVET CDACC, (2019). Competency Based Curriculum For Biotechnology Levels 6, 2019.

Laws of Kenya, Biosafety Act No. 2 of 2009

The National biosafety Act No.2 of 2009 has been established in Kenya to regulate activities in genetically modified organisms, to establish the National Biosafety Authority. This was done to ensure human and animal health during the practice of Biotechnology in Kenya. Part 4 sections (a) to (c) define the objects of the Law;

The objects of this Act are—

(a) to facilitate responsible research into, and minimize the risks that may be posed by, genetically modified organisms;

(b) to ensure an adequate level of protection for the safe transfer, handling and use of genetically modified organisms that may have an adverse effect on the health of the people and the environment; and

(c) to establish a transparent, science-based and predictable process for reviewing and making decisions on the transfer, handling and use of genetically modified organisms and related activities.

These regulations iron out any doubt and controversy that the practice of Biotechnology is poses danger to human life in Kenya. It's arguably true that the implementation of Biotechnology in Kenyan economy is long overdue and must be prioritized to achieve Kenya's Vision 2030 and worlds Sustainable Development Goals (SDGs). However, despite the existence of the government policies, the gap is lack of emphasis on the Curriculum implementation of Biotechnology in TVET sector.

Conclusion

Even though there is a shortage of adequate staff for biotechnology, there is a workforce that can initiate the training of Biotechnology in Siaya Institute of Technology. The existent laboratory infrastructure in the institute is highly developed but needs slight modifications to accommodate the training and practice of Agricultural Biotechnology. However, involvement of other areas of biotechnology may require additional tools and equipment in the laboratory.

Recommendations

- This survey should be replicated in all TVET institutions in Kenya to determine further the readiness of TVET institutions for Biotechnology curriculum implementation
- There is need for public-private partnership in funding infrastructure and capacity building in Biotechnology for TVET sector
- An Associations of Biotechnologists in TVET institutions should be established to provide professional advice to the Ministry of Education on matters concerning Biotechnology in the TVET sector
- The existent government policies should be more emphatic on the implementation of Biotechnology curriculum in Kenyan TVET institutions

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SIAYA INSTITITUTE OF TECHNOLOGY

QUESTIONNAIRE

LEVEL OF PREPAREDNESS IN BIOTECHNOLOGY: A CASE STUDY OF SIAYA INSTITUTE OF TECHNOLOGY

NAME OF YOUR INSTITUTION……………………………………………………………………………………………………

1. Please indicate your gender
   Male ◯ Female ◯

2. Please indicate your level of education
   Diploma ◯ B.ED ◯ Msc ◯ PhD ◯

3. What subjects do you teach in technical education?

   ………

4. Do you teach Agricultural Biotechnology?
   Yes ◯ No ◯

5. If yes, indicate the topic or sub-topics you teach during Agricultural Biotechnology class (tick where applicable)
   Tissue culture ◯ Plant breeding methods ◯ Genetic ◯ engineering

6. Have you ever had any in-service professional development for teaching Agricultural Biotechnology?
   Yes ◯ No ◯

7. If yes, indicate the main focus of the in-service course

   ……………………………………………………………………………………………

8. Please check the number that best describes your present attitude

   (1) I don't know about Agricultural Biotechnology ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯
   (2) I am concerned about improving what presently I know about biotechnology ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯

   (3) I am not concerned about teaching biotechnology ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯
   (4) I would like to discuss the possibility of teaching Biotechnology ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯

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(5) Are you concerned about integration of biotechnology in the TVET curriculum

9. Do you have a Biology laboratory in your institution?
   Yes ◯ No ◯

10. Do you have any of the following equipment/machines in your biology laboratory? (Tick (√) or cross (X) appropriately)

Autoclave	◯	Incubator	◯
pH meter	◯	Culture tubes	◯
Microwave	◯	Culture tube racks	◯
Domestic pressure cooker	◯	Thermometer	◯
Refrigerator	◯	Graduated cylinders	◯
Freezer	◯	Micropipettes	◯
Laminar flow transfer hood	◯	pipettes	◯
Digital balance	◯	Bunsen burner	◯
Sterilizer	◯	Distiller	◯
Water bath	◯	Media dispenser	◯
DNA transilluminator	◯	PCR thermo cycler	◯
UV visualizer	◯	Electrophoresis tank	◯
Spectrophotometer	◯	Vortexing machine	◯

11. Does your institution have a well-designed tissue culture laboratory?
    Yes ◯ No ◯

12. If yes, specify the main partitions of the laboratory

………

………