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Full Length Research Paper

Stakeholders' perceptions and application of biotechnology in agricultural industries in Swaziland

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Agriculture, forestry, and manufacturing contribute about 47.6% of Swaziland gross domestic product (GDP). A descriptive type of research was used to investigate the application of biotechnology in the agricultural based industries in Swaziland. Stakeholders were invited to a workshop where the participatory approach for data collection was used. Data were also collected by means of field visits and interviews. Data were analyzed using Micro Soft Excel statistical package. The findings showed that about 12% of the agricultural industries were not involved in biotechnology. Over 60% of the stakeholders responded that they were users of biotechnology materials and over 30% were involved in the production of biotechnology materials. Perceptions of respondents towards acceptance of modern biotechnology products have shown that respondents strongly agreed, mean = 6.0, with the statement 'drought tolerant maize should be grown in the country'. The major problems that should be addressed by modern biotechnology were development of vaccines (95%) and development of drought tolerant crops (80%). Results showed that modern biotechnology had a minor role in maize field pest control (20%) and in herbicide tolerance (15%). Biotechnology research is imperative for food security in Swaziland and this could be regulated by establishing a sound biosafety framework.

Key words: Agricultural industries, biotechnology, Swaziland, transgenic products.

INTRODUCTION

The importance of Biotechnology is well documented. It is important in the pharmaceutical industry for the production of antibiotics and therapeutic proteins (Primrose, 1986). It is important in agriculture for improvement of plant yields, animal yields and disease control strategies (Fitt and Llewellyn, 1995; Peacock, 1996). Biotechnology is used in the food industry for the production of novel foods, value added food stuff, food ingredients such as biopolymers used for secondary effect like emulsification, stabilization of emulsions, suspension of particulates, control of crystallization, inhibition of synthesis, encapsulation and film formation (Primrose, 1986; Roller and Dea, 1992). Products produced by biotechnological techniques are also used in the oil industry, paint industry, and paper industries (Sutherland, 1992; Roller and Dea, 1992). Biotechnology is useful in environmental management control such as in the utilization of industrial waste for the production of value added products (Schwartz and Bodie, 1985; Dlamini and Peiris, 1997ab). It is also used for biosorption and bioremediation strategies (Lawson et al., 1984; Volesky, 1995; Tsetse, 2003).

In animal agriculture, biotechnology has been used to manipulate the physiology and the genetic make up of farm animals to enhance their performance or to get novel products. The manipulations of the reproductive physiology of farm animals include artificial insemination and embryo transfer (ET) and these have enabled diverse usage of superior dams and sires (Ransom et al 1996). Biotechnology has also resulted in hormonal manipulation of animals to improve their performances. In dairy animals, daily injection of bovine somatotropin (BST) to increase milk yields has been practiced. Porcine somatotropin has also been used to increase average daily gain and lean tissue development while decreasing back-fat in pigs (Ransom et al., 1996).

Modern biotechnology has produced transgenic animals. Previous research on BST included methods for

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production of transgenic BST animals to boost BST level in the animal thus eliminating daily administration problems of the hormone (Ransom et al., 1996). Transgenics have also been developed to modify the composition of biomolecules that are produced by these animals (Simons et al., 1987). Attempts (Ward, 1989) have been made to develop transgenic sheep containing genes from *Escherichia coli* for encoding the enzymes serine transiltylase (SAT) and O-acetylserine sulfhydrylase (OASS) for catalyzing the convention O-acetylserine sulfhydrylase of serine to cystein. Cystein is required for wool growth and is rated limiting in most pastures. Recently, modern biotechnology has promoted transgenic pharming, whereby animals are genetically engineered to produce desired compounds that could be sold to treat particular diseases (Puchooa, 2004; Daneshyar et al., 2006). Pigs have been modified to produce human haemoglobins and rabbits to produce pomp correcting enzymes (Primrose, 1986).

Other animal biotechnology procedures that have been developed include: cloning, production of stem cell cultures, use of probiotics and use self-multiplying biomolecular nutrients (Fernades and Shahani, 1990; Old and Primrose, 1991; Playne, 1995). In Africa, International Livestock Research Institute (ILRI) has used biotechnology to produce antigens that can be used in diagnostic tests for tick–born diseases. In 1996, ILRI released a recombinant east cost fever vaccine for field trials (Mugabe, 2002).

In plants, biotechnology applications have aided several plant breeding and propagation techniques for improvement of food production world over (Nuffield Council on Bioethics, 2003). Some of such examples include tissue culture (Jones, 1999; Ammoety and Essegbey, 2003), anther cultures, protoplast cultures, micro-propagation (Xu, 1995), production of double haploids, induced mutations, production of F1 hybrids and marker aided selection.

Modern biotechnology has resulted in production of genetically engineered plants (Peacock, 1996; Sasson, 1995). This has resulted in the production of transgenic plants specifically developed for micronutrients enrichment, crop pests, disease, herbicide and abiotic stress resistance. Insecticidal genes from *Bacillus thuringiensis* have been inserted into cotton against Lepidopteran pests, and into cauliflower against *Helicovorpa armigera* (Fitt and Llewellyn, 1995; Peacock, 1996). Results from China have shown that there are cost benefits of Bt cotton when compared to non-Bt cotton (Nuffield Council on Bioethics, 2003). Transgenic tobacco against mosaic virus and transgenic potatoes against PSTV have been produced in China (Xu, 1995). Transgenic maize containing the *B. thuringiensis* genes have also been produced (Sasson, 1995). Recombinant DNA technology has also been used to produce plants that have abiotic stress resistance. Such plants have the ability to survive harsh climatic or soil conditions such as moisture stress and soil salinity (Nuffield Council on Bioethics, 2003). For an example, transgenic rice containing genes that regulate production of trehalose isolated from *Indica* rice have been produced. It is claimed that these transgenes may increase yield under drought conditions by 20% (James, 2002). Genetic modifications of crops have also been done to produce crops that contain higher levels of essential nutrients for human nutrition. Transgenic rice that has high levels of ß-carotene in the rice endosperm (Nuffield Council on Bioethics, 2003) has been produced.

The greatest concern however, regarding the use of transgenic plants for pest control is development of resistant pests (Fitt and Llewellyn, 1995; Tabashnik, 1995). It is feared that transgenic plants may rapidly select for resistant insect pests. Recent reports from elsewhere (University of Arizona, 2008), have shown that bollworms resistant Bt cotton have been identified. Another fear is loss to biological diversity of the plant and fears of the unknown when the transgenes are released to the environment (Tabashnik, 1995; Elistrand et al., 1999). On the aspect of human health, there are concerns about development of antibiotic resistant gut pathogens when antibiotic resistant gene markers have been used, cause of allergic reactions and violation of individual religious ethics (Thompson, 2000).

Like many countries in the developing world, the economy of Swaziland is heavily depended on agriculture. In 1997, it was reported that agriculture, forestry, and manufacturing contributed 47.6% of Swaziland gross domestic product (GDP) (Swaziland Government, 1998). Manufacturing alone accounted for 75% of the 47.6% GDP. It was further reported that over 70% of the manufactured products were processed agricultural and forestry products. In Swaziland, biotechnology has recently been one of the topical issues. However, there are many gaps and questions regarding the use of biotechnology in the country. These questions include:

1. Which industries are using biotechnology?
2. What aspects of biotechnology are used by the industries?

The specific objectives that guided the study were to:

1. Investigate the adoption of biotechnology by primary and secondary producers in agricultural based industries in Swaziland.
2. Identify the biotechnological techniques that can be used by agricultural based industries in Swaziland to promote yields or control pests and diseases.

METHODOLOGY

Description of the study area

Swaziland is located in south eastern Africa, sandwiched between Mozambique on the eastern part and South Africa on the other parts (Figure 1). It is located between latitude 25° 30' and 27° 30' south and longitude 30° 30' and 32° 30' east covering an area of about 17 400 km2. It is divided into four geographical regions, from

Figure 1. Map of Southern Africa illustrate location of Swaziland in the region.

an altitude of 900 m in the lowveld to 1800 m in the highveld (Figure 2). The country has warm and wet summers and cool and dry winters with night frost. The annual rainfall ranges between 762 and 1143 mm in the highveld and between 508 and 590 mm in the lowveld. The climate of the country is near temperate in the highveld and subtropical in the lowveld (SADC, 2005). Agriculture plays a great role in: income generation particularly for the rural community; provision of raw materials for the manufacturing industries; and generation of export products for foreign exchange. The major export products are: Sugar, wood pulp, citrus fruits, beef, live animals, textiles, soft drink concentrates and coal (SADC, 2005). The major imports are food and feed ingredients, manufactured products, machinery and transport materials, mineral fuel and chemical related products. The major trading partners for the country are: South Africa, Mozambique, SADC, United States of America, United Kingdoms, Singapore, Japan, France, European Union, Brazil, Argentina and the rest of Africa. It is reported that in 2003, Swaziland was the biggest supplier of soft drink concentrate to the rest of Africa (SADC, 2005).

Design of the study

The study used a descriptive type of research. As a descriptive research, the researchers described the specific biotechnological techniques that are already in use in the agricultural based industries of Swaziland and those that should be introduced to: improve resistance against pests and diseases, yields and performance of plants and animals; and to improve industrial waste treatments strategies. This information is valuable for the development of a biosafety framework that must be in place to regulate the application of biotechnology in the country.

Population and sample selection

The target population of the study was all agricultural based industries that produce primary or secondary products and policy makers. A stratified random sampling procedure was followed. Ninety stakeholders were invited to participate in the research, of these; sixty five honoured the invitation and participated in the data collection workshop. Sample selection was done from each of the following agricultural industries: the cotton industry, the maize industry, the sugar industry, the pineapple/ fruit industry, the beef industry, the poultry industry, the dairy industry, the seed industry and the animal feeds production industry. This procedure ensured that all categories were represented. Participants were also selected to represent technical advisers and top management from the agricultural industry. Participants were also selected from relevant policy makers in the Ministry of Agriculture and Cooperatives; Ministry of Tourism and Environment; Ministry Enterprise and Employment and from non-governmental organization (NGO's).

Data collection

Data were collected using questionnaires and round table discussions with stakeholders. The questionnaires were designed following literature review. They were reviewed to establish validity and pilot tested to ensure reliability. Stakeholders were invited to a workshop where the participatory approach for data collection was followed. Participants were first asked to define and briefly discuss

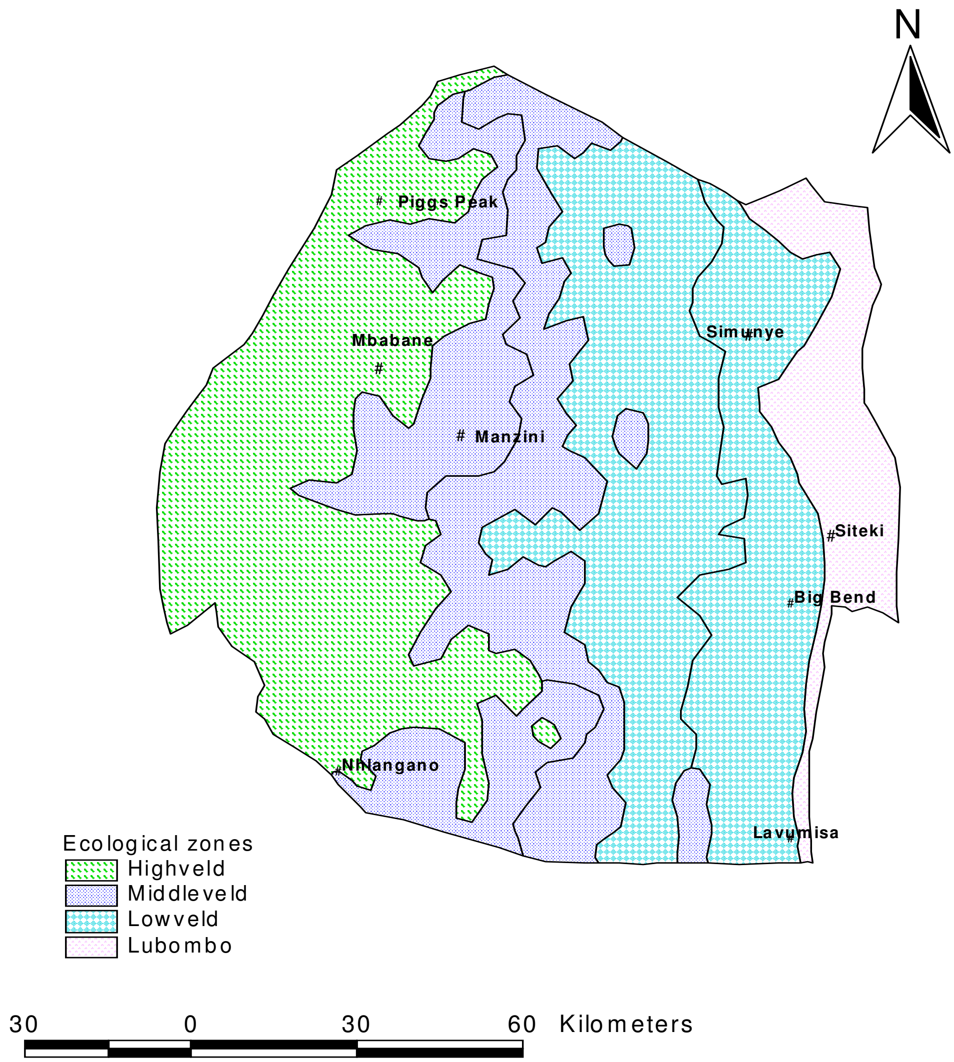

Figure 2. Map of Swaziland illustrating physiographic regions.

what they understood about biotechnology. This was followed by an informative descriptive review of biotechnology by the researchers. Then stakeholders were asked to complete the questionnaire. Field visits and interviews were also conducted.

Data analysis

Data collected from the participatory research were analyzed by computing means and percentages using Micro Soft Excel statistical package.

RESULTS

When stakeholders were asked if they were involved in biotechnology, 75% responded that they were involved in teaching about biotechnology (Figure 3). These were mainly the educational establishments, research institutions and extension sections of the public and private sectors. These results have also shown that 60 and 35% of the respondents were involved in using biotechnology for plant and animal performance improvement respecttively, indicating an awareness of the role of biotechnology in agriculture. Results presented in Figure 3 also showed that 38% of agricultural based industries were producers of primary biotechnology products. Such products included ethanol and fermented beverages and dairy products. Overall, only 12% of the stakeholders responded that they were not involved in any biotechnology activity.

Figure 4 showed percentages of respondents that used biotechnologies in crop based industries. The results showed that most industries used liquid fertilizer (82%), followed by tissue culture (76%) and plant growth regulators (70%). Very few farmers use plant anther cultures (16%). Figure 5 showed that artificial insemination, 80%, and animal growth regulators, 70%, were the major biotechnologies used in animal production. Artificial insemination (AI) is used mainly in the cattle industry. All

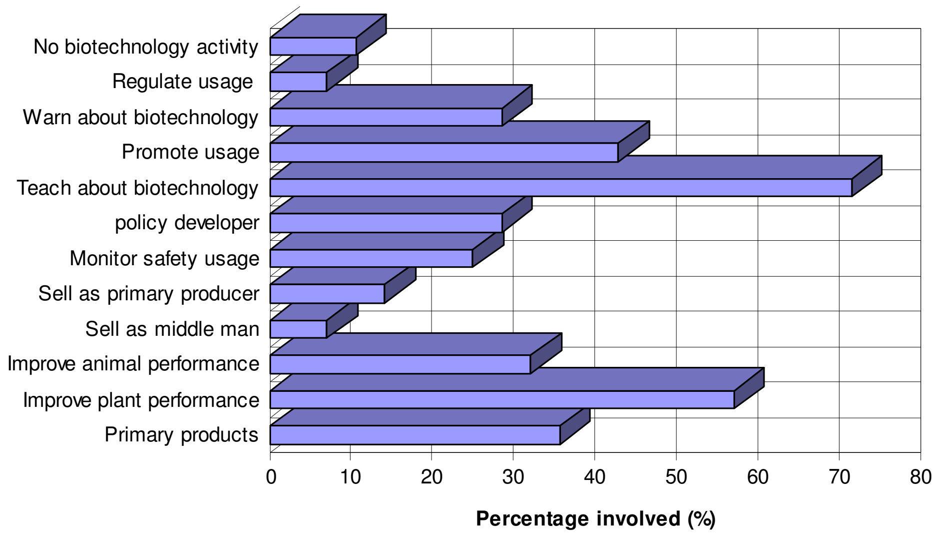

Figure 3. Percentage of respondents involved in biotechnology in the agricultural industries of Swaziland (n = 65).

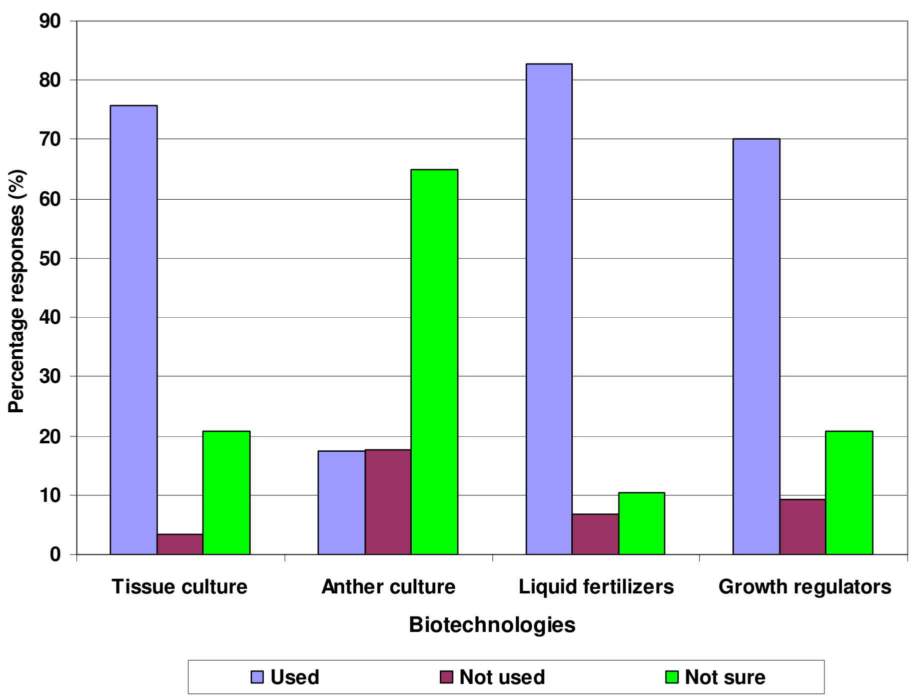

Figure 4. Opinions of stakeholders about biotechnologies used in crop production in Swaziland.

commercial dairy farmers use AI, including specialized small scale farmers on Swazi nation land (SNL).

The general biotechnologies that can be undertaken by agricultural based industries in Swaziland are presented in Figure 6. Fermentation is the major biotechnology technique, 90%, followed by biomolecular nutrient application, 59%, and the least practiced is bioremediation, 12%. About 80% of the respondents were uncertain if any bioremediation strategies were practiced in their Industries. When respondents were asked whether products of modern biotechnology are already in the country, about 41% of the respondents indicated that they could be using plant products of recombinant DNA technology (Figure 7). As presented in Figure 7, other products of

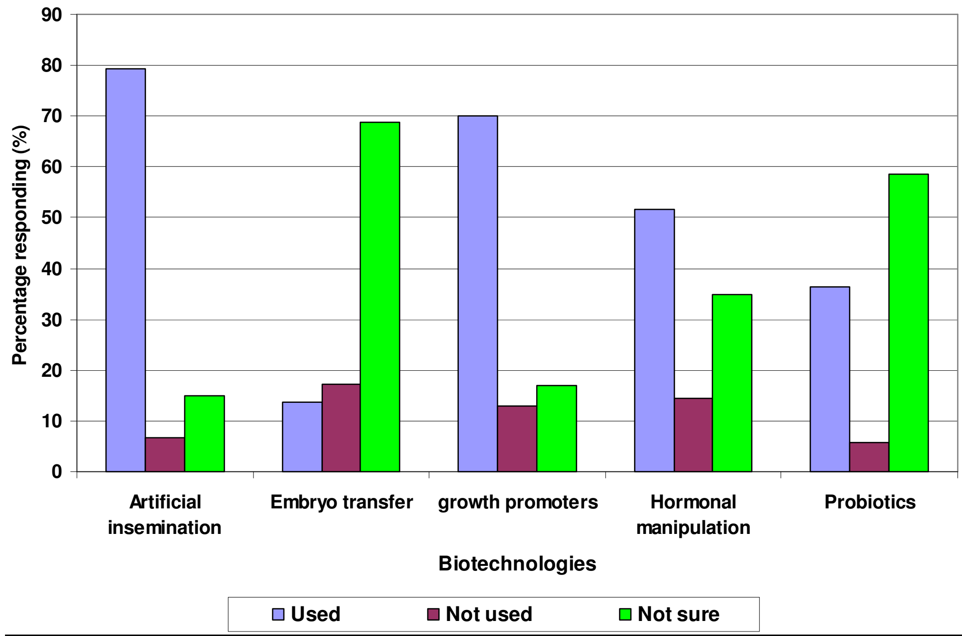

Figure 5. Opinions of stakeholders about biotechnologies used in animal production in Swaziland.

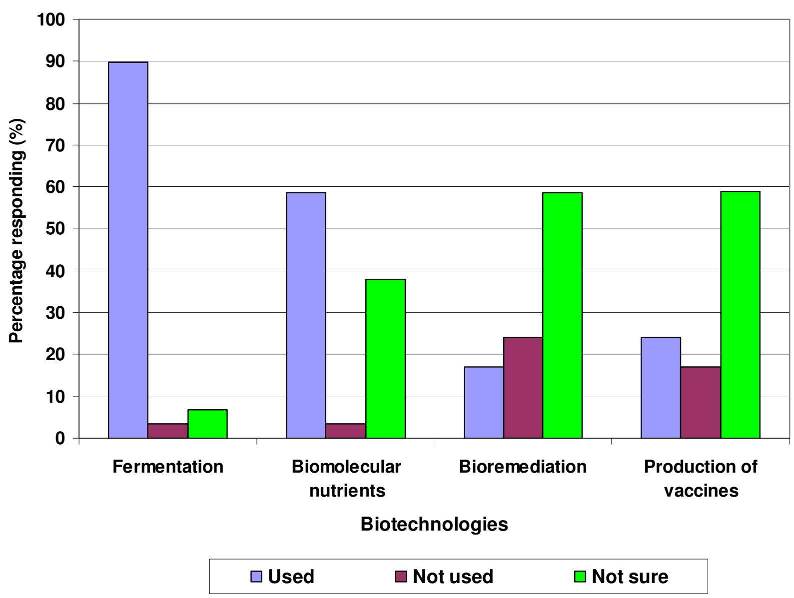

Figure 6. Opinions of stakeholders about the application of biotechnology in agricultural based industries in Swaziland.

modern biotechnology that respondents suspected could be already in the country were transgenic animals (18%), animal clones (20%) and stem cell cultures (30%).

Results presented in Table 1 show that respondents had a high level of tolerance towards acceptance of modern biotechnology. Respondents agreed with all the statements that were advocating introduction of genetically modified organisms into the country. A highest mean rating of 5.7 was given to the statement about 'permitting the growing of drought tolerant crops in the country'. The private sector rated this statement with a mean score of 5.9, meaning strongly agreeing. A lowest mean rating of 3.8 was given by the public sector who slightly agreed to the statement 'Allow use of genetically modified

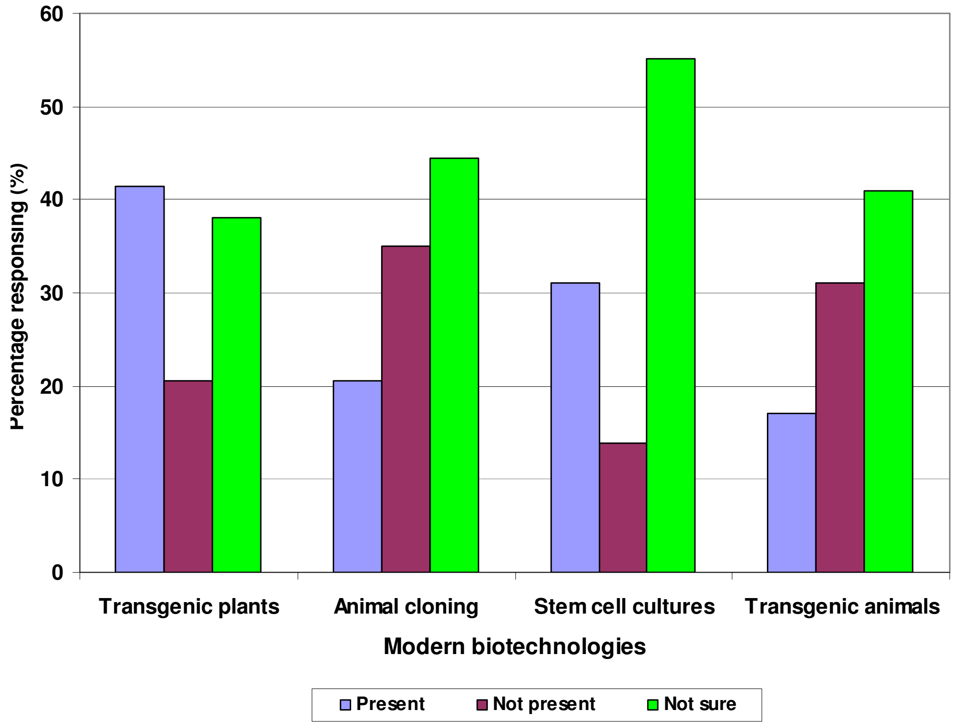

Figure 7. Opinions of stakeholders about possibility of existence of modern biotechnology in Swaziland.

Table 1. Perceptions of respondents on acceptability of modern biotechnology in Swaziland.

Perceptions	Public sector (n = 13)	Parastatal sector (n = 27)	Private sector (n = 25)	Total (n = 65)
Growing genetically modified cash crops could be allowed	4.5 ± 1.4	5.3 ± 0.9	5.3 ± 1.0	5.1 ± 1.1
Allow production of drought tolerant transgenic crops	5.5 ± 0.6	5.6 ± 0.65	5.9 ± 0.30	5.7 ± 0.52
Growing genetically modified field crops could be allowed	4.5 ± 0.4	4.5 ± 1.1	5.4 ± 0.81	4.8 ± 0.77
Allow use of Genetically modified crops for animal feeds.	3.8 ± 1.5	4.8 ± 0.99	4.6 ± 1.4	4.4± 1.3
Products from genetically modified organisms should be allowed into the country	4.5 ± 1.1	4 ± 1.2	4.7± 1.3	4.4 ± 1.2

Rating scale: 6 = Strongly Agree; 5 = agree; 4 = slightly agree; 3 = slightly disagree; 2 = disagree; 1 = slightly disagree. ± 1 SDV.

crops for animal feeds'.

Table 2 presents perceptions of respondents on the major requirements for the implementation of modern biotechnology in Swaziland. Respondents strongly agreed with the statements that: 'Field trials should be done prior to commercial growing of field crops, 5.77; Public and private sector should collaborate in biotechnology research, 5.77; The university should take a lead in biotechnology education and research, 5.54. Respondents agreed with the statement: 'Government should monitor production of transgenics' (5.4) and that 'all production of genetically modified products must be registered', 5.3. Respondents did not agree with the 'statements that genetically modified food should be rejected' (2.6) and a lowest rating mean score was given to the statement that 'there should be a ban on the importation of all product of recombinant DNA technology' (2.01). When respondents were asked to rank some agricultural problems as major or not major that could be addressed by recombinant DNA technology (Table 3), development of vaccines was ranked by 95% of the respondents as major. This was followed by development of drought tolerant crops, 85%, control of ectoparasites, 80% and post harvest pests, 75%. All these were perceived by the respondents as the major problems that could be addressed by modern biotechnology. Whereas development of herbicide tolerant crops, control of maize field pests, improvement of live-stock yields were perceived as not major problems that should be addressed by recombinant DNA technology.

Table 2. Perceptions of respondents' on requirements for the implementation of modern biotechnology in Swaziland.

Perceptions	Public sector (n = 13)	Parastatal sector (n = 27)	Private sector (n = 25)	Total (n = 65)
Genetically modified producers must be registered	5 ± 1.1	5.2 ±.83	5.9 ± .30	5.37 ± .74
Field trials should be done prior to commercial growing of field crops	5.8 ± .41	5.6 ± .63	5.9 ± .30	5.77 ± .45
Government should monitor production of transgenics	5 ± 1.1	5.6 ± .48	5.7 ± .47	5.43 ± .68
Food aid from genetically modified organisms must be rejected	3.2 ± 1.9	3.0 ± 1.6	1.7 ± .79	2.63 ± 1.43
The university should lead in biotechnology education & research	5.7 ± .52	5.4 ± 1.3	5.5 ± 1.0	5.53 ± .94
Public and private sector should collaborate in biotechnology research	5.8 ± .41	5.6 ± .87	5.9 ± .30	5.77 ± .53
Products from genetically modified organisms should not be imported	2 ± .6	2.3 ± 1.1	1.9 ± 1.1	2.07 ± .93

Table 3. Ranking of major agricultural problems that should be addressed by recombinant DNA technology in (n = 65).

Problem	% Ranking it as major	% Ranking it as minor
Drought tolerant crops	80	20
Post harvest pest control	75	25
Control of livestock ectoparasites	80	20
Vaccines development	95	10
Soil fertility problems	62	38
Weeds control	40	60
Field crops pests control	20	80
Improved animal yields	30	70
Improved crops yields	40	60
Development of herbicide tolerant crops	15	85

DISCUSSION

In Africa, different countries practice biotechnology at different stages of development varying from micro propagation to the manipulation of recombinant DNA and production of transgenic plants. Mugabe (2002) categorized African countries into three broad groups according to their level of biotechnology development. The first group includes those countries that are generating and commercializing biotechnology using advanced techniques such as recombinant DNA technology. The second group includes those countries that are engaged in genetic engineering but have not developed products and processes. The final group includes those countries that are engaged in the second generation of biotechnology such as tissue culture. Mugabe (2002) did not put Swaziland under any of these three categories.

Results presented in this study have indicated that this country could be placed under the third group, countries that are engaged in the second generation of biotechnology such as tissue culture and fermentation. The results presented here have shown that 38% of agricultural based industries were producers of primary biotechnology products. Such products included ethanol, fermented beverages and dairy products. As reported before, Swaziland is a major producer of cane sugar (SADC, 2005). During sugar processing, molasses is produced as a by – product. Ethanol is a major value added product produced using molasses as fermentation substrate.

Results have shown that over 80% of agronomist use liquid fertilizers. This indicates an enormous opportunity for the biofertilizer industry in the country. As reported elsewhere, biofertilizers are an environmentally friendlier practice of improving soil fertility (Garg et al., 2001; Mekonnen et al., 2002). It can be noted however, that although the demand for biofertizers is so high in the country, there are no pilot plants locally for their production. All the current products are imported and this is so despite that technology for their production is not complex (Juma and Konde, 2002). Agricultural based industries are also users of tissue culture materials, particularly in the banana and eucalyptus plantations. Results have also shown that a majority (79%) of livestock farmers use artificial insemination (AI) and very few (12%) use embryo transfer (ET) yet if both AI and ET can be used, rapid improved livestock performances can be realized. Although the results have shown that about 70% of farmers use animal growth regulators, it is unlikely that these include steroid hormones because use of such is prohibited under the Swaziland livestock act. Growth promoters used are most probably probiotics.

Eighty percentage of the respondents were uncertain if any bioremediation strategies were practiced in their industries. This is a cause of great concern since biotechnology may play a very important role in environmental management such as in the utilization of industrial waste for the production of value added products (Schwartz and Bodie, 1985; Dlamini and Peiris, 1997ab). When the sugar industry uses molasses for the production of ethanol, environmental pollution is prevented. Ethanol can also be used to produce biofuel for motor vehicles. Motor vehicle fuel may be blended with ethanol like in Brazil and North America (United Nations, 2004).

The benefits to the environment of using ethanol blends as motor vehicles' fuel are enormous. Firstly, carbon emissions are reduced (United Nations, 2004). Secondly, ethanol based fuels have significantly reduced fine particulate matter ($PM_{2.5}$). A reduction in $PM_{2.5}$ of 36 and 64% in normal and high emitters, respectively, has been reported (Mulawa et al., 1997). Thirdly, toxic emissions such as benzene are up to 25% lower in ethanol blend using motor vehicles than in those using fossil derived fuels (Kirchstetter et al., 1996).

Bioremediation refers to the process of using living organisms to remove contaminants, pollutants or unwanted substances from soil or water (Zaid et al., 2003). Microbial polysaccharides have been reported to be capable of removing heavy metals from sewage treatments (Ghosh et al., 1990; Okoh et al., 2007). Reports have shown that biopolymer producing microorganisms can remove heavy metals from solutions by chelation (Volesky, 1995; Ahalya et al., 2003; Tsetse, 2003; Alluri et al., 2007). The use of microbial exopolysaccharides to remove heavy metals from effluent treatment is of great interest to studies of metal removals from industrial effluent and adds to the control of environmental pollution.

Modern biotechnology has recently been one of the topical issues. This has been confirmed by Mugabe (2002), who observed that there are on-going debates on the acceptability of modern biotechnology in many communities. This has resulted in development of policies to ensure appropriate regulation of modern technology (EC, 2002). In this country, like in many countries and regions, the public debate has been focusing on genetically modified organisms (GMOs). There have been a lot of uncertainties about societal acceptance of the GMO technology. Results presented in this study have shown that respondents suspected that products of modern biotechnology such as transgenic plants and animals might already be found in this country. This could be due to the fact that most of the seeds used in the country are imported and most of the grains received as food aid are imported from countries that are known producers of transgenic plants, yet the country has not yet fully implemented its biosafety framework. Results however, have also shown that agricultural based industries in this country had a high level of tolerance towards acceptance of modern biotechnology. All three stakeholders of the agricultural based industries namely: public, parastatal and private sectors, agreed that transgenics may be allowed into the country provided good biosafety control measures are put in place. From a policy point of view, the precautionary approach towards the adoption and application of modern biotechnology is advocated. It centers on the principle of prevention. It involves the use of risk assessment techniques, environmental impact assessment and decision making on whether to allow or to prohibit the technique (MaCkenzie et al., 2003).

The Cartegena protocol on biosafety is one example of an international instrument that seeks to ensure adequate levels in trans-boundary movements of living modified organisms (CBD, 2004). Swaziland has acceded and ratified the protocol. The country has also developed a national biosafety framework, and is in the process of finalizing the biosafety Act as a requirement for the implementation of the protocol. It is anticipated that once the biosafety bill has been accented into law, biosafety regulatory committees and risk assessment procedures and methods of notification will be developed.

The major problems that should be addressed by modern biotechnology include development of vaccines, control of cattle ectoparasites such as ticks, control of post harvest pests in maize grains and development of drought tolerant crops. Ticks are a major problem in the livestock sector. They are responsible for several tick borne diseases to cattle such as heart water and red water. Consequently, the Swaziland government implements compulsory weekly cattle dipping program using various acaricides. This, however, is a very costly program (Mukasa-Mugera et al., 2003). Weevils are the major post harvest pests for maize. The major problem with current control strategies for both weevils and ticks is that the chemicals used have very high mammalian toxicity and have been abused on several occasions by people who commit suicide. Contrary to the findings of this study, most recombinant DNA technology has targeted traits that were ranked by respondents as minor problems in the agricultural based industries of Swaziland. The commercialized genetically engineered crops are cotton, soybean, canola, and corn. The traits addressed include herbicide and insect resistance (Nuffield Council on Bioethics, 2003). Recent reports, however, have shown that drought tolerant maize hasbeen developed.

Conclusion

The involvement of Swaziland in biotechnology is in the second generation of biotechnology such as tissue culture, fermentation and artificial insemination. Most agricultural based industries are aware of the biotechnologies that can be used to improve yield and performances, whereas less than 12% are not aware of any biotechnology that they can use. Agricultural based stakeholders are not apprehensive towards acceptance of modern biotechnology, they believe that with appropriate regulatory structures, modern biotechnology can be used to produce drought tolerant crops, vaccines, tick and weevil control systems.

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