非洲撒哈拉以南的转基因作物状况

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摘　要　在非洲撒哈拉以南地区,将近 70%的人口生活在农村地区并以农业为生。然而,相比于世界上其他地区,这一地区对可持续的农业技术接受较为缓慢,再加上较低的农业生产率,使其成为了粮食净进口地区。农业生物技术不仅是提高农业产量的工具,同时也为保证粮食安全和消除贫困带来了巨大的机遇。目前,仅南非、布基纳法索和苏丹在商业化规模种植转基因作物。许多非洲国家已经或正在建立针对现代生物技术应用的监管框架,有 9 个国家正在对一些转基因作物进行限制性田间试验,这些转基因作物具有受农场主和消费者欢迎的优良性状。本文综述了转基因作物在非洲撒哈拉以南地区的应用情况,聚焦于转基因作物的研究、发展以及使用。同时对非洲部分地区各选取 2 个国家进行说明,分别是非洲南部的南非和马拉维、非洲东部的肯尼亚和乌干达以及非洲西部的加纳和布基纳法索。介绍了这 6 个国家管理转基因作物使用的法规并提出了向前推进的建议。

关键词　非洲撒哈拉以南地区;粮食安全;可持续农业;小规模农场主;转基因作物;功能性监管系统;限制性的田间试验

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农业是大多数非洲国家经济发展的支柱产业,其对消除贫困和保证粮食安全至关重要。它贡献了超过 25%的国内生产总值(GDP)、50%的出口创汇并且雇佣了约 75%的劳动力[1]。农业规模较小并且面临许多挑战,尤其表现在以下几个方面:由于优良作物品种的缺乏导致的较低的农业生产率,较低的土壤肥力,病虫害导致的作物损失,稀少的、不稳定的水资源供给,有限的农业用地。

据估计,非洲撒哈拉以南地区人口在 2015 年将增长到 20 亿。政策制定者、农场主和消费者面临的挑战是解决很多非洲国家所面对的既存粮食安全问题。在 2012 年 7 月,非盟国家元首和政府首脑会议宣布 2014 年为"非洲农业和食品安全年",这一举措即是为了设定目标来提高农业生产率并使耕作方式适应气候变化,这对于非洲的发展前景至关重要。

生物技术在农业可持续增产方面扮演重要角色。在非洲,用于农业的生物技术手段有组织培养、分子鉴定、分子标记辅助选择、分子诊断以及转基因。目前,组织培养在许多国家被用于咖啡、香蕉、菠萝以及块根农作物的种植材料的快速获得。组织培养技术在肯尼亚部分地区小农场主中的应用使得他们种植的脱毒香蕉的产量得以提高。然而,很少国家着眼于从现代农业技术中获益,相反大多数国家仍然困扰于潜在的危险。由此导致目前仅有 3 个国家(南非、布基纳法索和苏丹)在商业化种植转基因作物(表 1)。

目前非洲在商业化种植的转基因作物有棉花(南非、苏丹和布基纳法索)、玉米(南非)和大豆(南非)(表 2)。布基纳法索和苏丹 2013 年的 Bt 棉花的种植面积分别增长了 50%(从 2012 年的 313 781 hm^2 增长到了 474 229 hm^2)和超过 200%(从 2012 年的 20 000 hm^2 增长到了 61 513 hm^2)。

目前有许多研究机构和大学参与到公私合营联盟关系中,期望通过遗传改良得到受农场主和消费者欢迎的性状的不同农作物品种。非洲地区关于转基因作物的研究和发展见表 3。

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表 1　非洲国家转基因作物的现状

Table 1　Status of genetically modified(GM) crops in Africa

阶段 Stage	国家 Countries
商业化生产	布基纳法索;埃及[1)];南非;苏丹
限制性田间试验	布基纳法索;喀麦隆;埃及;肯尼亚;加纳;马拉维;尼日利亚;南非;乌干达
研究阶段	布基纳法索;喀麦隆; 埃及;加纳;肯尼亚;马拉维;马里;毛里求斯;纳米比亚;尼日利亚;南非;坦桑尼亚;突尼斯;乌干达;津巴布韦
发展研发能力	布基纳法索;布隆迪;埃及;肯尼亚;摩洛哥;塞内加尔;坦桑尼亚;乌干达;赞比亚;津巴布韦;贝宁;喀麦隆;加纳;马拉维;马里;毛里求斯;纳米比亚;尼日尔;尼日利亚;突尼斯;阿尔及利亚;博兹瓦纳;埃塞俄比亚;马达加斯加;卢旺达;南非;苏丹

1)埃及政府已停止商业化生产 The Egyptian government has imposed a moratorium and halted commercial production.

表 2　2013 年非洲种植的不同种类及不同性状的转基因作物[1)]

Table 2　GM crops and traits grown in Africa in 2013　　hm^2

国家 Countries	作物 Crop	总面积 Total area	转基因作物面积 GM area	特定性状种植面积 Trait area		
				IR	HT	IR/HT
南非	黄色玉米	1 150 000	1 041 000	267 635	243 684	530 065
	白色玉米	1 580 000	1 322 000	412 707	165 347	774 725
	大豆	520 000	478 000		478 000	
	棉花	8 000	8 000		400	7 600
布基纳法索	棉花	690 971	474 229	474 229		
苏丹	棉花	69 132	61 530	61 530		

1)来源 Source:James (2013); IR:抗虫 Insect resistant; HT:耐受除草剂 Herbicide tolerant; IR/HT:既抗虫又耐受除草剂 Stacked insect resistant/herbicide tolerant.

表 3　非洲国家正在研发的转基因作物及相应性状[1)]

Table 3　GM crops and traits under research and development in Africa

作物 Crop	已进入限制性田间试验的目标性状 Traits at CFT stage	国家 Countries	非洲的组织/机构 Organisations/Institutions in Africa
玉米	抗虫,抗旱	SA; EG; KE; UG	AATF, ARC-SA; NARO-UG; KARI-KE;
棉花	抗虫,除草剂耐受	SA;KE;GH,BF;MW; CR	LUNAR/BUNDA College-MW; INERA-BK; SARI-GH
大豆	除草剂耐受	SA	私人公司
木薯	抗病毒,营养增强	UG; KE; NG	NRCRI-NG; NARO-UG; KARI-KE;
甘薯	抗病毒,抗象鼻虫,营养增强	UG; KE; GH	AfricaHarvest; NARO-UG; KARI-KE; CRI-GH
香蕉	抵抗真菌抗细菌性枯萎病	UG	AATF, NARO-UG; KARI-KE
豇豆	抗虫	NG; BF; GH	AATF, IAR-NG; INERA-BK; SARI-GH
水稻	氮高效利用,抗盐,水资源高效利用	UG; GH	AATF, NARO-UG; CRI-GH
高粱	营养增强	NG	AfricaHarvest; IAR-NG; KARI-KE

1)SA:南非 South Africa; EG :埃及 Egypt; KE:肯尼亚 Kenya; UG:乌干达 Uganda; GH:加纳 Ghana; BF:布基纳法索 Burkina Faso; MW:马拉维 Malawi; CR :喀麦隆 Cameroon; NG:尼日利亚 Nigeria;AATF:非洲农业技术基金会,肯尼亚 Africa Harvest:Africa Harvest Biotech Foundation International,Kenya; ARC:农业研究委员会,南非 Agricultural Research Council,South Africa; INERA:环境与农业研究所,布基纳法索 Institut de l'Environnement et de RecherchesAgricoles,Burkina Faso; SARI :草原农业研究所,加纳 Savannah Agricultural Research Institute,Ghana; NRCRI :国家块根作物研究所,尼日利亚 National Root Crop Research Institute,Nigeria;NARO:国家农业研究组织,乌干达 National Agricultural Research Organisation,Uganda; KARI:肯尼亚农业研究所,肯尼亚 Kenya Agricultural Research Institute; CRI:作物研究所,加纳 Crop Research Institute,Ghana; IAR:农业研究所,尼日利亚 Institute for Agricultural Research,Nigeria.

至少有9个非洲国家(南非、布基纳法索、埃及、肯尼亚、乌干达、马拉维、尼日利亚、喀麦隆和加纳)正在针对本地种植的作物进行田间试验,这些作物包括香蕉、木薯、棉花、豇豆、玉米、水稻、甘薯以及高粱。最近,加纳还通过了棉花、水稻、豇豆和甘薯的限制性田间试验[3]。

撒哈拉以南非洲地区采用现代农业技术进展缓慢的一个原因是,发展转基因作物同时保证它们符合基于科学的监管要求实非易事。大多数非洲国家政府不管从财政上还是从推行有力政策上对科学和技术的投入都很少。因此,许多国家在健全现代农业技术应用的监管系统方面也进展极度缓慢。目前,有21个国家确立了生物安全监管框架;2个国家处于生物安全法案通过立法的最后阶段;27个国家仍然致力于在联合国环境署全球环境基因生物安全计划(http://www.unep.org/biosafety/national%20Biosafety%20frameworks.aspx)[4]的支持下起草各自国家的生物安全框架的草案;另有5个国家还未建立生物安全框架(表4)。表4是基于目前存储于生物安全资讯中心的数据[5]。

表4 非洲国家生物安全法律现状1)

Table 4 The status of biosafety legislation in Africa

生物安全文书 Biosafety instrument	国家 Countries
已制定生物安全法律	布基纳法索;喀麦隆;埃及;埃塞俄比亚;加纳;肯尼亚;马拉维;马里;毛里塔尼亚;毛里求斯;莫桑比克;纳米比亚;塞内加尔;南非;苏丹;斯威士兰;坦桑尼亚;多哥;突尼斯;赞比亚;津巴布韦
法律草案已准备妥当,等待通过成为法律	尼日利亚;乌干达
国家生物安全框架草案(联合国环境规划署/全球环境基金生物安全项目的指导)	阿尔及利亚;贝宁;博兹瓦纳;布隆迪;佛得角;中非共和国;乍得;科摩罗;刚果;科特迪瓦;刚果民主共和国;吉布提;厄立特里亚国;赤道几内亚;加蓬;冈比亚;几内亚;几内亚比绍;莱索托;利比里亚;利比亚;马达加斯加;摩洛哥;尼日尔;卢旺达;圣多美与普林希比共和国;塞拉利昂
无国家生物安全框架	安哥拉;加那利群岛;索马尼亚;南苏丹;西撒哈拉

1)来源 Source:http://bch.cbd.int/protocol/parties/.

1 部分国家的报告

1.1 南 非

早在20世纪90年代,南非首先开始评估农业生物技术产品。意识到围绕转基因作物的问题和担忧涉及科学、经济学、社会学、贸易和政治等方方面面,在当时作为一个过渡性质的生物安全监管实体的南非科学与工业研究理事会(CSIR)成立了南非遗传研究委员会(SAGENE)。这个委员会负责对政府、工业和大众在涉及转基因物种的活动中如何保证安全提供建议,这类活动需依照农业害虫监管法案(Act No.36 of 1983)的修正案获得审批通过。

然而在意识到农业害虫法案不适用于转基因物种之后,一个横跨多个部门的委员会得以成立,这一委员会的成立就是为了起草一个可以监管转基因物种的研究、生产、使用和应用的法案来使其对人类和环境的风险最小化。这一工作的成果就是转基因生物法案(Act No.15 of 1997)的颁布并于1999年12月正式开始执行。自2000年以来,涉及转基因物种的活动均在此法案的监管之内并由农林渔业部(DAFF)负责执行。

转基因生物法案覆盖所有涉及转基因物种的活动,诸如进出口、运输、研究、生产、使用及贮藏。在一个转基因物种可以使用的决定作出之前,需要进行一个多学科的风险评估,这一过程需要科学顾问委员会和跨政府决策机构——执行理事会的参与。这些评估主要集中于转基因生物可能对人类、动物和环境带来的潜在风险并保证符合国际标准制定结构的规定。

转基因生物法案为转基因物种的不同用途提供监管依据——包括实验室或者温室的研究(封闭使用)、作为食物或饲料(商品许可)、限制性的环境释放(限制性的田间试验)、商业化释放(正式释放)等。在南非不同环境条件下的转基因物种表现及安全数据获得之前,是无法获得正式释放的申请授权的。每一授权均限定在特定条件并且其执行情况会受到农林渔业部的监测。

2003年8月14日南非批准了生物安全议定书。转基因生物法案在2006年也进行了修订(GMO Amendment Act,Act No.23 of 2006)——这一修订主要是为了规定南非在这一议定书前提下应尽的义务。

1997 年，Bt 棉花成为南非第 1 个商业化种植的转基因作物。目前南非仅有 3 种转基因作物获得批准进行商业化种植，分别是玉米、棉花和大豆。这些作物经改良后对特定害虫具有抵抗力以及（或者）能耐受某些除草剂。一些旨在获得转基因玉米、棉花和甘蔗新品种正式释放授权的田间试验仍在进行中。

2001 年，科技部门制定了“南非国家生物技术战略”。这一举措着眼于通过启动科技及其配套产品和服务的研发来解决其健康、工业、农业部门对基于科学创新的急切需求。然而，人们很快就发现这一战略有着明显需要跨越的鸿沟。此战略重点关注的是资本能够快速获得回报的、与市场联系紧密的技术的商业化过程，而不是形成一套完善的针对生物技术产品的创新价值的产业链。随着 2013 年“生物经济战略”的发布，这一战略也随之修改：焦点转变为生物技术部门与 ICT 部门、环境署、社会科学和其他技术——尤其是本土知识实践系统（IKS）——的结合来创造满足针对农业、健康和工业部门需求的一体化解决方案和工业应用。

1）小农场主应用抗虫抗除草剂玉米的成功案例。虽然小农场主为南非的粮食产量做出了很大的贡献，但是他们仍需要更好的耕种方法来提高其产量和收入。政府已通过各省的农业部门推行了一系列的计划来提高这些农民务农和经商的技能，并通过向他们介绍高效率的工具和使用方法来克服目前面临的农业和气候的双重挑战。AfricaBio 公司与豪登省（Gauteng）农业与农村发展部在过去 8 年来一直都有合作关系，他们一起向豪登省许多新兴农民以及他们的社群推荐抗虫和耐受除草剂的玉米，并且很直观地证明农业生物技术在作物保护上所扮演的重要角色，他们的努力使得产量提高并且农民的收入也得到增长。

在比勒陀利亚以北 40 km 的 Masopane 有一个名为 Onverwaght 的农场，这个农场坐落在一个斜坡上，远远望去绿色的玉米地就像是铺上了一层地毯。

在这片土地上，35 岁的 Sophie Mabhena 追逐着她的农场梦想。Mabhena 在这片 385 hm^2 的农场上长大，这片农场的产出支持了她的学业以及她整个家庭的生计。作为一个种植玉米的农民，Mabhena 如果想要获得好的收成以确保将来能在磨坊主那里卖出好价钱，田间害虫和杂草的控制就是关键。

Mabhena 于是种植了既抗虫又耐受除草剂的转基因玉米，这种玉米含有可以抗虫的 Bt 基因；同时也对除草剂有耐受性。不同程度的蛀茎夜蛾侵染，会使玉米产量减产 20%～80%。对玉米穗轴的侵害则会为霉菌感染玉米创造条件，这又转而产生霉菌毒性物质，当人们食用这些受污染的作物后，可能会引起严重的健康问题。“我对既抗虫又耐受除草剂的玉米非常满意，因为它可以减少农药使用和田间人工除草而产生的费用，但是最主要的收益还是来自于种植这种优良玉米品种所带来的高产和高收入”，Mabhena 说道。

尽管目前仅在农场的小片地区种植了转基因玉米，但是 Mabhena 相信这种玉米是对抗害虫和杂草的保证，她也因此从未考虑再重新种回以前的玉米品种。对她来说，她的选择是一直稳步地增加种植转基因玉米的面积，这样她就可以向磨坊主出售更多的玉米。她目前的愿望是可以扩大养殖场的规模，她的养殖场目前已有 75 圈牛、绵羊、山羊和鸡。同时她还说她在另一小块土地上种植的蔬菜也快要可以采摘到市场上去卖了。

“我不会再去种植那些传统玉米了，已经回不去了”，Mabhena 说道。“从产量角度考虑，通过使用这种既抗虫又耐除草剂的玉米种子，我获益很多；并且在未来 5 年内，我想增加转基因玉米的种植面积到 100 hm^2，那时我将会成为一个顶级农场主了。”

Sarah Buda 女士在 2008 年了解到 Bt 玉米，自此之后每年都会种植 2 hm^2 的这种玉米。她说她和她的丈夫是在机缘巧合之下成为种植玉米的农民的。

“我以前一直在种植蔬菜，但是当我参加豪登省农业与农村发展部组织的展览会并接触到 Bt 玉米之后，我对种植 Bt 玉米很有兴趣并且毫不后悔。”Buda 说道。

Buda之前由于不能很好地开发她的土地，因此将土地出租了，但是现在她计划好好利用起她比勒陀利亚市外的Varkfontein农场222 hm^{2}中的140 hm^{2}土地。“自从我接受种植Bt玉米的训练之后，我对商业种植变得雄心勃勃，因为我已厌倦仅仅只是一个新兴农民，我想要更多的收入来发展我的农场并且实现我作为一个农场主的价值”，Buda说道，“我之前用井水来灌溉蔬菜而只用雨水灌溉玉米；以后我也会用井水来灌溉我的玉米了”

在第1年里，Buda种植了转基因玉米。她意识到这是一个好的品种，还因此举办了一个田间展示日来向其他农场主展示种植Bt玉米的好处。

“对我来说，Bt玉米比传统玉米更有优势，因为没有蛀茎夜蛾感染这些玉米并且没有必要使用农药”，Buda说道。她同时还惋惜到“一些人不停地抱怨转基因玉米，担心它对健康的影响，但是我们已经食用过转基因玉米了，什么事都没发生。许多人也吃过来自转基因玉米的玉米粉。”Buda的下一步计划就是在整个农场上种植Bt玉米，同时她对种植转基因大豆也饶有兴趣，“由于已享受到种植转基因玉米带来的益处，我正在鼓励其他农场主采用这一技术，因为农业也是一门生意，我们需要赚钱。如果你种植一种作物，但是它却不能给你带来任何收益，这种事你会做么？”

使用抗“终结者”(Round Up)除草剂的种子已经帮助Buda解决了杂草的难题，但是在她的蔬菜里控制杂草的技术仍然在研发过程中。

对另一种植Bt玉米的农民Motlatsi Musi来说，农业生物技术的到来就像一场及时雨。“当我2005年第一次见到Bt玉米之后，我就觉得这产品不错。与我之前43年传统品种的种植经验相比，我立马意识到之前的农药滥用对我已造成伤害”，在位于约翰内斯堡市外的奥利范次夫莱的Fun Valley经营农场的Musi说道，“虽然我没有太好的手段解决滥用农药问题，但是我喜欢Bt种子技术，因为它自带了一个解决工具。转基因玉米相比以前的传统玉米能够让我增收34%。”

Musi说对他来讲最大的不同就是：当同时种植1 hm^{2}传统玉米和1 hm^{2}转基因玉米时，需要对前者施加很多农药，但是后者却完全不需要农药。

“播种密度与产量也有关系，此次我每公顷播种了55 000棵玉米，共收获了7 t玉米。作为农民，我们必须赚钱，尽管农产品的市场价格常常得不到保障。”

“我将来的计划是保证我和村子里的粮仓储满粮食——不仅是Bt玉米，也包括其他各品种的玉米”，Musi说道。“我想继续种植更多的玉米，但是必须首先解决如何获得足够多的种子的问题。”

Musi同时也养殖猪和其他牲畜，他将他的Bt玉米卖给了商业农民。他已有足够的收入来供养他的儿子读大学，同时他也购买了一批更好的设备来继续他的Bt玉米的种植。

2)问题。在南非，转基因作物的发展和应用主要有以下两个挑战：

①公共资助的研究还没有达到商业化的程度。南非的生物技术研发目前遭遇资金缺乏、缺少合作的困境。然而，有迹象表明，政府倾向于将生物技术作为一个解决目前社会、医疗和经济等许多问题的良方。人们希望在这一新的生物经济战略——本土知识实践系统的指导下，商品和化学药品的制造以及医药和疫苗的生产将能引起关注并吸引投资者带来更多资源促进生物技术的研究和发展。

②关于转基因作物的误导和谣言。南非的反对转基因运动不断增加，并且主要宣传以下五个方面错漏百出的谣言。

· 关于转基因副产品的食品安全——目前还没

有证明转基因作物及其食品对人类来说是安全的。自从转基因作物于 1996 年在美国、1997 年在南非进行商业化种植以来，很多人就一直在表达这种担忧。

• 转基因对小农场主的影响以及大型跨国公司对种子的控制——由于对高产的偏好，转基因生物的应用将会挤垮小农场主并让他们成为跨国种子公司的俘虏。这一观点忽略了每一个农场主可以自愿选择种植什么这一事实。

• “超级病菌”和“超级杂草”的产生——使用转基因技术会促进对抗生素有抗性的“超级病菌”和对除草剂有抗性的“超级杂草”的产生，而这两者的产生会需要更多有毒性的化学药品。

• 对其他植物的“污染”——转基因作物的 DNA 能够混入其他非转基因植物的 DNA 中。

• 长期风险——转基因生物的长期风险还未被充分鉴定并管理。因此，反对转基因的团体要求强制标识所有转基因副产品并对食品生产厂家和销售者施加压力以使他们采购非转基因的食品。科学上已有一致意见认为转基因作物加工后的食品与传统食品相比并没有更高的风险。

3)建议。南非已有 17 年的转基因种植经验。这个国家有健全的监管体系，因此，这一区域在生物安全培训以及交流方面起到主导作用。

另外需要有更多的声音来拥护这一技术的应用。那些支持这些技术的人——如科学家和农民——已证实了转基因作物种植可以带来益处。支持转基因作物的原因有：转基因植物有更强的抗病性和更高的产量；已有明确的科学意见认为来源于转基因作物的食品相对于传统食品没有更高的风险；没有一例因人食用转基因食品而导致疾病的报道；转基因作物种植对环境也是有益的。一些转基因作物具有“设计”好的内置的抗虫性，因此，这些植物与需要更多农药的非转基因作物相比，他们是一个更绿色更环保的选择。这些植物也可以被遗传改良至可以在贫瘠的土地、较低的温度、干燥的气候以及其他很多较为不利的条件下生长良好。

1.2　马拉维

马拉维一直以具有非洲国家中少数几个功能性的生物安全监管体系为荣。这个国家在 2000 年 5 月 20 日签订了生物安全议定书并在 2009 年 2 月批准执行。为了达到议定书的要求，马拉维的国会于 2002 年 10 月通过了生物安全法案。这一法案为生物安全议定书的施行提供了制度框架——由国家生物安全监管委员会、评议者、检查员和生物安全司法常务官等组成。环境事务局(EAD)——作为具有国家管辖权的机构——对生物技术的监管负有责任，它负责接受有关转基因生物的活动申请，加以评估后颁发许可证书。国家生物安全监管委员会是环境事务局的下属机构。

马拉维内阁于 2008 年 6 月 26 日批准了一项有关国家生物技术和生物安全的政策。在马拉维生物技术和生物安全的政策下，政府以及研发和其他服务交付的机构中，不同角色和职责是分开的。在马拉维，提出并发展相应生物技术是由国家科技委员会(NCST)授权的。国家科技委员会下辖国家生物技术委员会，后者的职责是促进生物技术的研究、提高公众意识以及协调生物技术的研究和发展。

农业和食品安全部设立了生物安全委员会制度，这一制度因农业生物技术和生物安全委员会而著名。它接受来自农业和食品安全部的技术和财政支持。

有利益相关者提出，成立一个马拉维生物技术和生物安全联盟来推进生物技术和生物安全，进而更好地改善生计。该联盟的成员包括决策者、科学家、私营部门的领导人、民间组织领导人和以个人身份加入的政府官员——也包括来自卫生、农业、环境、贸易和工业部门的公共和私营利益相关机构。马拉维生物技术和生物安全联盟总体目标是作为利益相关者的联合体来支持生物技术的安全和持续利用以及经济的发展以促进国家的发展和社会经济转型。

1)研发。在 2009 年，利隆圭(马拉维首都，译者注)农业和自然资源大学(前身是邦达农学院)提交了一份棉花的限制性农田试验申请。

2013 年 1 月 4 日，马拉维成为非洲南部继南非之后的第 2 个对 Bt 棉花进行限制性田间试验的国家。马拉维成功地在位于首都利隆圭市郊的利隆圭农业和自然资源大学进行了第 1 次 Bt 棉花的限制性田间试验。该试验结果表明，Bt 棉花比非 Bt 棉花更耐受棉铃虫攻击并且产量更高，产量高的原因是每株棉铃数增加而不是因为单个棉铃变大。分析表明种植 Bt 棉花的经济收益比传统棉花高出 50%。在 Chikhwawa、Salima 和 Karonga，Bt 棉花

种植区科研流动站进行重复限制性田间试验的许可已获得批准。

2)问题。

①监管障碍。尽管马拉维成功地进行了转基因作物限制条件下的田间试验，但是却耗费了2年时间才得到环境事务局的批准。马拉维的监管系统仍不健全，因此，需要更多支持来增强其能力以应对未来几年将汹涌而入的限制性田间试验/商业化申请。

②反转基因的激进运动。马拉维正处于发展Bt棉花的关键时期——正在进行多试验点的限制性田间试验。可以预期的是，对这些试验宣传力度的增加将会使得反对转基因的行为更加活跃，因此需要快速回应并提高公众的意识来反击这些反对转基因的行为。这项任务可以通过公私合营联盟成立独立组织着手。

此外，政府官员需要得到支持并获得正确的信息；同时政府向民众做出保证，只有被认为对人类健康和环境安全的转基因作物才会被批准用于商业用途。

3)建议。需要注意的方面有：

①支持国家生物安全监管委员会进行生物安全交流。

②对其委员会的成员进行培训以提高农业生物技术与安全委员会作为一个科学的安全评估团队的服务质量并加强其进行风险评估的能力。

③由于生物安全司法常务官、生物安全委员会成员以及国家生物安全监管委员会的成员具有监管生物安全的职责，也需要对他们进行培训。同时针对检查员进行关于监测以及合规标准的培训也是必须的。

④促使生物安全司法常务官和国家生物安全监管委员会的成员去参加其他国家的功能性生物安全委员会召开的会议。

⑤提高转基因作物的公共认知水平。

⑥建立和维护马拉维生物技术和生物安全联盟作为支持生物技术发展和可持续利用的发言人的角色。

1.3 肯尼亚

肯尼亚是东非共同体中的第一个起草生物安全监管草案和指导方针的国家，其在1998年就已在全国科学技术委员会的指导下起草此法案。这个国家在2000年5月15日签署了生物安全议定书并于2002年1月24日开始执行。生物安全法案作为监管农业生物技术的法律框架于2009年颁布，随后又于2011年8月公布了实施条例——这一条例为转基因作物的商业化种植铺平了道路，之后的重点则转向了保障这一生物安全体系有效运作至关重要的基础设施建设以及相应程序上来。

肯尼亚的生物安全框架——2009年的生物安全法案就已经初具规模，这一框架主要涉及国家生物安全管理局，这个机构的任务是协调不同的相关机构以促进转基因作物的安全研究、转移、处理及应用。国家生物安全管理局的运作是在管理委员会的监管之下进行的，该管理委员会成立于2010年4月。当涉及到农业生物技术时，这个管理委员会对肯尼亚政府的行为具有决定权。国家生物安全管理局截至目前仅处理过遏制和限定转基因作物使用的申请。

1)研发。尽管对转基因产品的禁令仍未取消，但研发工作仍在继续。针对Bt棉花、抗病毒木薯、生物强化的木薯、抗旱玉米、抗病毒甘薯和非洲抗虫玉米的限制性田间试验正在进行中。大多数此类研究是在肯尼亚农业研究所与国际研究机构的合作下进行的。

2)问题。主要存在以下两个方面的问题：

①管理方面的挑战。基于2012年9月法国一所大学公布的塞拉利尼的抹黑转基因的研究结果，肯尼亚总统姆瓦伊·齐贝吉在2012年11月颁布了禁止转基因进口和生产的禁令。那项研究认为老鼠的癌症和食用转基因食品有关。肯尼亚自此决定对与转基因有关的条款进行进一步评估，这使得蒙巴萨港口的转基因玉米进口也进入一个瓶颈期。目前各方正在努力希望能解除此禁令。

②小规模的农场主也被禁止使用正在进行限制性田间试验的转基因作物品种。

3)建议。

①目前最紧迫的事情是撤销针对转基因产品进口的禁令。

②说服政府撤销针对转基因产品的禁令。

③对监管者进行培训并开发相应的监管设施和程序以应对目前仍在进行的限制性田间试验的转基因作物的商业化种植和转基因作物的进口。

1.4 乌干达

乌干达国家科学技术理事会于1998－1999年

起草了生物安全监管法案，并于 2000 年 5 月 24 日签署了生物安全议定书。作为生物安全议定书的签署国，乌干达有义务施行必要的政策、法律和行政规定来保证现代生物技术的安全使用。作为推行国家生物安全框架的重要举措，乌干达在 2008 年通过了国家生物技术和生物安全政策。贯彻这一政策实施的法令已经起草，但是仍然需要议会通过。

由于没有明确的法律，乌干达一直在临时决议下管理现代生物技术的应用。临时的生物安全监管系统是由乌干达国家科学技术理事会负责协调的，该理事会制定了涉及转基因生物研究的框架。因而，该法令的颁布可以保证现代生物技术的发展和应用采取更加统一的方法来保证生物安全。财政部门、经济规划与发展部门和乌干达国家科学技术理事会共同负责此法案。

1)研发。乌干达正在研究和开发的转基因作物的列表令人印象深刻(表 2)。大多数的生物技术研究活动是由国家农业研究组织(NARO)的国内科学家实施或是通过国际合作进行的，这些研究的目的是解决诸如病虫害、干旱和营养不良的挑战。

2)问题。

①生物安全法案。经过限制性区域试验后的改良品种，在提供给农民之前需要有相应法律监管。生物安全法案在乌干达成为法律仍是一个不小的挑战，这导致了转基因计划将仍会卡在田间试验这一步，而不能朝正式释放前进一步。

②反转基因的激进运动。游说团体对生物安全法案获得通过的抵制已经成功地扰乱了争论并拖延了政治进程，关于这一技术带来的风险和益处的平等和实质性的对话已无可能。国内辩论充斥着被误导和危言耸听的宣传活动，这助长了无谓的担忧。

3)建议。

①支持国家生物安全法案的通过。

②支持和培训国家生物安全局发布限制性田间试验，这将导致通过批准的转基因作物在乌干达正式释放(商业化种植)。

1.5 加　纳

加纳在 2003 年 5 月 30 日加入生物安全议定书。加纳的生物安全制度最初是由 2008 年 5 月通过的法律文书推动的(LI 1887：加纳生物技术管理法)，之后被 2011 年 12 月所通过的生物安全法所替代。依据该法，加纳建立了国家生物安全管理局(NBA)，随后成立了管理局的委员会并等待正式就职。加纳目前正在制定实施细则，以帮助实施该法案。在此期间，国家生物安全委员会的主要职责是对与生物安全有关的申请以及其他相关事宜进行审查和做出决定。

加纳在建设有效且功能健全的生物安全监管体系方面取得了良好进展。生物安全秘书处目前已经运作，并且负责协调加纳的生物安全活动。行政审查和处理相关申请能力的提高、监管职能的高效发挥以及生物安全方面决策能力的提升，已经帮助四起针对限制性田间试验申请的审查获得了成功。

此外，国家生物安全管理局在相应职责的政府部门指示下已经制定了生物安全法案的实施准则(ABNE，2013)。

1)研发。位于库玛西的作物研究所和位于塔马利的草原农业研究所正在对 4 个已通过审核的品种进行限制性田间试验。他们分别是：Bt 棉花、豆荚螟抗性的豇豆、营养强化的甘薯以及水与氮元素高效利用并耐盐的水稻。

2)问题。

①监管能力。在制定和实施标准操作流程、处理和审查生物安全应用、采用最佳方案进行安全监管、检查和监督限制性的田间试验等方面进行培训是非常有必要的。

②反转基因的激进运动。加纳国内讨论转基因生物也是充斥着被误导和危言耸听的反对转基因的宣传活动，助长了无谓的担忧。

3)建议。

①提供战略指导、技术支持和能力建设工作，以确保国家生物安全管理系统的正常运转。

②确定并实施沟通策略，加强主要行动者和利益相关者之间的生物安全知识和意识。这将有助于促进转基因决策过程中公众的有效参与。

③帮助加纳批准和执行名古屋- 吉隆坡补充议定书中关于赔偿责任和补救措施的条款。

1.6 布基纳法索

布基纳法索也于 2000 年 5 月 24 日签订了生物安全议定书。其 No. 005－2006/AN 号法案也于 2006 年 3 月 17 日通过，以管理布基纳法索的生物安全事务。由于生物安全制度发挥作用，Bt 棉花在 6 年的田间试验完成后于 2008 年经国家批准进行商业释放。布基纳法索也因此成为继南非和埃及之

后第 3 个可以种植转基因作物的非洲国家。

2010 年布基纳法索政府开始审查和修订原有的国家生物安全法律，并在 2012 年 12 月以修订版法律被国民议会采用。

1)研发。布基纳法索的研究及开发活动是在以下机构进行的：负责进行转基因作物田间试验的农业研究所、正在进行转基因蚊子研究的 Muraz 中心以及国际畜牧研究中心等。

布基纳法索批准通过了 5 个转基因作物品种。其中包括 2008 年就已商业化种植的抗虫(Bt)棉花、除草剂耐受的棉花、对豆荚螟有抗性的正在进行限制性田间试验的豇豆。

2)问题。非洲在生物技术应用方面的典范。布基纳法索的经验是如何将生物技术成功引进到非洲的一个典范。它表明，有政府的大力支持，生物技术可以克服法律框架、技术官僚所带来的难题；并且发展中国家的私营部门和中小型生产者联合起来的商业模式可以支持生物技术并使之维持下去。

3)建议。

①严格遵守修订后的法律，并起草实施细则。

②关于修订后的法律的采用，国家机构必须加强生物安全的沟通计划。

③对于限制性田间试验和正式释放后监测和评估的监督能力建设必须给予大力支持。

2 结 论

转基因作物是农业史上应用最快的技术。然而，它在非洲地区的应用受到了限制。目前仅南非、布基纳法索、苏丹和埃及在商业化种植转基因作物。不过，许多项目正在对非洲农民的转基因新品种进行试验——从抗旱玉米到抗虫抗病的香蕉、豇豆、甘薯以及营养增强的甘薯和高粱。

转基因作物的引入需要有功能完善的生物安全机制来评估和管理潜在的风险。随着现代生物技术的进步，发展基于科学的、可实际操作的生物安全措施显得尤为重要。不幸的是，非洲南部地区国家少有具备功能完善的生物安全法律框架，其余国家最多也只有临时的生物安全框架。有足够严格的监管草案来防范真正确定的风险；同时在进行充分的风险评估时对数据可靠性有辨识能力的决策者，所有这些都具有相当大的影响。例如，太多的信息往往使制定决策受到干扰，使时间和精力从识别潜在风险的重要任务中转移至他处 ，这样一来就会减缓流程并增加相应成本。因此，尽管在研发和人力资本方面进行了大量投资，转基因在非洲的潜力尚未被充分认识。目前，开发出的具有优良性状的转基因作物还未到达非洲农民的手中。

对转基因作物一味地谣言攻击不符合非洲的利益。有关转基因作物谣言的扩散导致了困惑和恐惧，从而减缓了该技术的应用。以科学为基础进行真实的生物技术信息的传播和讨论是非常有必要的，这样一来人们就可了解到农业上新的创新正在帮助其他国家的农民满足他们的食品安全需求。同时利益相关者——尤其是科学家、记者和政策制定者——团结起来并进行开放式的讨论、分享有关生物技术的真实信息以及如何以负责任的方式利用这些信息为大家谋福利是很有必要的。农民应该有权选择和使用新的农业措施来帮助他们解决在田地里所面临的挑战，包括病虫害、干旱、洪涝和炎热等。

在此，我们提出建议，非盟和各国政府应多支持撒哈拉以南非洲国家的需求，以评估转基因作物在增强非洲大陆的粮食安全和消除贫困方面的益处。

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The status of GM crops in sub-Saharan Africa

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Abstract In sub-Saharan Africa, nearly 70% of the population live in rural areas, and they depend on agriculture for their livelihood. However, the adoption of sustainable agricultural technology has been slower than in other parts of the world. In addition, the low agricultural productivity of sub-Saharan Africa makes the region a net importer of food. Agricultural biotechnology can be used as a tool for increasing agricultural productivity, while also offering significant opportunities for attaining food security and poverty alleviation. So far, only South Africa, Burkina Faso and Sudan are planting genetically modified (GM) crops at a commercial scale. Many African countries have developed, or are in the process of developing, regulatory frameworks for modern biotechnology application, and close to 9 countries are conducting confined field tests of GM crops with farmer-preferred and consumer-oriented traits.

This paper reviews the status of GM crop adoption in sub-Saharan Africa, with a focus on the research, development and use of GM crops. Two countries from each regional block of Southern Africa (South Africa and Malawi), East Africa (Kenya and Uganda), and West Africa (Ghana and Burkina Faso)—are reviewed. Regulations governing the use of GM crops and adoption issues, and recommendations on the way forward—are made for each of these six countries.

Key words sub-Saharan Africa; food security; sustainable agriculture; small-scale farmers; GM crops; functional regulatory systems; confined field trials

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Abstract In sub-Saharan Africa, nearly 70% of the population live in rural areas, and they depend on agriculture for their livelihood. However, the adoption of sustainable agricultural technology has been slower than in other parts of the world. In addition, the low agricultural productivity of sub-Saharan Africa makes the region a net importer of food.

Agricultural biotechnology can be used as a tool for increasing agricultural productivity,While also offering significant opportunities for attaining food security and poverty alleviation. So far, only South Africa, Burkina Faso and Sudan are planting genetically modified (GM) crops at a commercial scale. Many African countries have developed, or are in the process of developing, regulatory frameworks for modern biotechnology application, and close to 9 countries are conducting confined field tests of GM crops with farmer-preferred and consumer-oriented traits.

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1 Introduction

Agriculture is the backbone of economic growth for the majority of African countries, and is essential for poverty reduction and food security. It accounts for more than 25% of the gross domestic product (GDP), 50% of export earnings, and employs about 75% of the labour force[1]. Agriculture is predominantly small scale and faces many challenges. These include, *inter alia*, low farm productivity due to lack of improved crop varieties, low soil fertility, crop losses from pests and diseases, scarce and unreliable water supply, and limited land availability.

It is expected that the population of sub-Saharan Africa will grow to nearly 2 billion by the year 2015. Policymakers, farmers and consumers are thus challenged to reach a clear vision in order to address the existing food insecurity issues facing a number of African countries. In July 2012, the African Union (AU) Assembly of Heads of State and Government, declared the year 2014 to be the year of Agriculture and Food security in Africa, in order to prioritise and set targets to, *inter alia*, increase agricultural productivity and adapting farming to climate change—as key factors to Africa's development prospects.

Biotechnology can play a significant role in increasing agricultural production in a sustainable way. In Africa, biotechnology tools used in agriculture include tissue culture, molecular characterisation, marker-assisted selection, molecular diagnostics, and genetic modification (GM). Currently, tissue culture is applied in many countries for rapid multiplication of planting materials for coffee, banana, pineapple, and root crops. The application of tissue culture in the production of pathogen-free bananas has in fact increased yields for small-scale farmers in parts of Kenya. However, few countries have focused on the benefits of modern biotechnology, and most countries are still focusing on the potential risks. As a result, only three countries (South Africa, Burkina Faso and Sudan) are currently growing GM crops commercially (see Table 1).

The GM crops under commercial production in Africa are cotton (South Africa, Sudan and Burkina Faso), maize (South Africa) and soybean (South Africa) (see Table 2). In 2013, Burkina Faso and Sudan increased their Bt cotton hectares by 50% (from 313 781 hectares in 2012 to 474 229) and just over 200% (from 20 000 hectares in 2012 to 61 513), respectively[2].

There are several research institutions and universities involved in public-private partnerships,

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Table 1 Status of Genetically Modified (GM) crops in Africa

Stage	Countries
Commercial production	Burkina Faso; Egypt*; South Africa; Sudan
Confined field testing	Burkina Faso;Cameroon; Egypt; Kenya; Ghana; Malawi;Nigeria; South Africa;Uganda
Contained research	Burkina Faso; Cameroon; Egypt; Ghana; Kenya; Malawi;Mali; Mauritius; Namibia; Nigeria; South Africa; Tanzania; Tunisia; Uganda; Zimbabwe
Developing capacity for research and development	Burkina Faso; Burundi; Egypt; Kenya; Morocco; Senegal; Tanzania; Uganda; Zambia; Zimbabwe; Benin; Cameroon; Ghana; Malawi; Mali; Mauritius; Namibia; Niger; Nigeria; Tunisia; Algeria; Botswana; Ethiopia; Madagascar; Rwanda; South Africa; Sudan

*The Egyptian government has imposed a moratorium and halted commercial production.

Table 2 GM crops and traits grown in Africa in 2013—IR (Insect Resistant); HT (Herbicide tolerant); IR/HT (Stacked Insect Resistant/Herbicide Tolerant)

Country	Crop	Total area(ha)	GM area (ha)	Trait area (ha)		
				IR	HT	IR/HT
South Africa	Maize-Yellow	1 150 000	1 041 000	267 635	243 684	530 065
	Maize-White	1 580 000	1 322 000	412 707	165 347	774 725
	Soybean	520 000	478 000		478 000	
	Cotton	8 000	8 000		400	7 600
Burkina Faso	Cotton	690 971	474 229	474 229		
Sudan	Cotton	69 132	61 530	61 530		

Table 3 GM crops and traits under research and development in Africa

Crop	Traits at CFT stage	Countries	Organisations/Institutions in Africa
Maize	Insect resistance, drought tolerance	SA; EG; KE; UG	AATF, ARC-SA; NARO-UG; KARI-KE;
Cotton	Insect resistance, herbicide tolerance	SA; KE; GH, BF; MW; CR	LUNAR/BUNDA College-MW; INERA-BK; SARI-GH
Soybean	Herbicide tolerance	SA	Private companies
Cassava	Viral resistance Nutrient enhancement	UG; KE; NG	NRCRI-NG; NARO-UG; KARI-KE;
Sweet potato	Viral resistance, insect (weevil) resistance, nutrient enhancement	UG; KE; GH	AfricaHarvest; NARO-UG; KARI-KE; CRI-GH
Banana	Fungal resistance, bacterial wilt	UG	AATF, NARO-UG; KARI-KE
Cowpea	Insect resistance	NG; BF; GH	AATF, IAR-NG; INERA-BK; SARI-GH
Rice	Nitrogen-use efficient, salt tolerance, and water-use efficient	UG; GH	AATF, NARO-UG; CRI-GH
Sorghum	Nutrient enhancement	NG	AfricaHarvest;IAR-NG;KARI-KE

SA—South Africa; EG—Egypt; KE—Kenya; UG—Uganda; GH—Ghana; BF—Burkina Faso; MW—Malawi; CR—Cameroon; NG—Nigeria; AATF—African Agricultural Technology Foundation, Kenya; AfricaHarvest—Africa Harvest Biotech Foundation International, Kenya; ARC—Agricultural Research Council, South Africa; INERA—Institut de l'Environnement et de Recherches Agricoles, Burkina Faso; SARI—Savannah Agricultural Research Institute, Ghana; NRCRI—National Root Crop Research Institute, Nigeria; NARO—National Agricultural Research Organisation, Uganda; KARI—Kenya Agricultural Research Institute, Kenya; CRI—Crop Research Institute, Ghana; IAR—Institute for Agricultural Research, Nigeria.

to genetically improve various crops with farmer-preferred and consumer-oriented traits. The GM research and development activities in Africa are highlighted in Table 3 (above).

At least 9 African countries (South Africa, Burkina Faso, Egypt, Kenya, Uganda, Malawi, Nigeria, Cameroon, and Ghana) are conducting field trials on locally-grown crops—including banana, cassava, cotton, cowpea, maize, rice, sweet potato and sorghum. Recently, Ghana approved confined field trials for cotton, rice, cowpea and sweet potato[3].

In sub-Saharan Africa, one reason for the slow adoption of modern biotechnology, is that the capacity to develop GM crops and ensure they meet science-based regulatory requirements is somewhat limited. Most African governments contribute little to science and technology, either financially or through strong policies. Hence, the process of developing regulatory systems for modern biotechnology application has also been disappointingly slow for many countries. So far, 21 countries have established their biosafety regulatory frameworks, 2 countries are in the final stages of having their biosafety bills passed into law, 27 countries are still working on their draft national biosafety frameworks developed under the UNEP-GEF Biosafety project[4], and 5 countries have no national biosafety frameworks(see Table 4). Table 4 is based on the current records deposited in the Biosafety Clearing House[5].

Table 4 The status of biosafety legislation in Africa

Biosafety Instrument	Country
Biosafety legislation established	Burkina Faso; Cameroon; Egypt;Ethiopia; Ghana; Kenya;Malawi; Mali; Mauritania; Mauritius; Mozambique; Namibia; Senegal; South Africa; Sudan;Swaziland;Tanzania;Togo;Tunisia;Zambia; Zimbabwe
Draft legislation ready and awaiting passage into law	Nigeria;Uganda
Draft National Biosafety Framework (Developed under UNEP/GEF Biosafety Project)	Algeria; Benin; Botswana; Burundi; Cape Verde; Central Africa Republic; Chad; Comoros; Congo;Cote d'Ivoire; Democratic Republic of the Congo; Djibouti;Eritrea; Equatorial Guinea; Gabon; Gambia; Guinea; Guinea-Bissau; Lesotho; Liberia; Libya; Madagascar; Morocco; Niger;Rwanda; Sao Tome and Principe;Sierra Leone
No National Biosafety Frameworks	Angola; Canary Islands; Somalia; South Sudan; Western Sahara

Source:http://bch. cbd. int/protocol/parties/.

2 Selected country reports

2.1 South Africa

As early as 1990, South Africa started to evaluate the products of agricultural biotechnology. Recognising that the issues and concerns around genetic modification involved scientific, economic, social, trade and political aspects, the South African Committee for Genetic Experimentation (SAGENE) was established by the South African Council for Scientific and Industrial Research (CSIR)—as an interim biosafety regulatory body. This Committee was responsible for advising the government, industry, and the public, on the safety of activities involving genetically modified organisms (GMOs). Approvals for such activities were granted under an amendment of the Regulations of the Agricultural Pests Act(Act No. 36 of 1983).

It was realised, however, that the Agricultural Pest Act had not been written to handle GMO. Thus, an Inter-departmental Committee was initiated in order to draft an Act that would regulate the responsible development, production, use and application of GMOs in such a way as to minimise any risk to human beings and the environment. The result of this work led to the promulgation of the Genetically Modified Organisms Act (Act No. 15 of 1997) (hereafter GMO Act), which was implemented in December 1999. Since 2000, activities involving GMOs have been regulated under this Act, which is administered by the Department of Agriculture, Forestry & Fisheries (DAFF).

The GMO Act covers all activities involving genetically modified organisms—like imports, exports, transit, development, production, use, and storage. Before a decision on the use of a GMO is made, a multidisciplinary risk-assessment process is undertaken, which involves a Scientific Advisory Committee and the cross-governmental decision-making body, the Executive Council. These assessments focus on all potential risks the GMO may pose to humans, animals and the environment, and are carried out in line with the prescripts of international standard-setting bodies.

The GMO Act provides for the regulation of different classes of use of a GMO—including development in the laboratory or glasshouse (contained use), the use as food and feed (commodity clearance), confined environmental release (confined field trial), and commercial release (general release). No general release authorisation is granted, unless performance and safety data generated under various South African environmental conditions are obtained. Every authorisation is subject to specific conditions, and compliance is monitored by the inspection services of the DAFF.

South Africa ratified the Cartagena Protocol on Biosafety on 14th August 2003. The GMO Act was amended in 2006 (GMO Amendment Act, Act No.23 of 2006)—mainly to make provision for the country’s obligations under the Protocol.

Bt cotton was the first GM crop commercialised in South Africa—in 1997. South Africa has three GM crops to date, namely maize, cotton and soybean, which have been approved for commercial plantings. These crops have been modified to be resistant to specific insects and/or tolerant to certain herbicides. Field trials aimed at ultimate general release authorisation continue for new GM maize, cotton and sugarcane varieties.

In 2001, the Department of Science & Technology produced a “National Biotechnology Strategy for South Africa”. This was aimed at initiating the development of technologies and associated products and services—to address the vital science-based innovation needs of the country in the health, industrial and agricultural sectors. However, it soon became apparent there were gaps in the strategy. The strategy focused on commercialisation of technologies that were close to market and which represented a quick return on investment, instead of being formulated to develop an innovation value chain for biotechnology-based products. The strategy was revised in 2013 with the publication of “The Bioeconomy Strategy”, in which the focus has shifted to developing a bio-economy where the biotechnology sector joins forces with the ICT sector, environmental agencies, the social sciences and other technologies—especially Indigenous Knowledge Systems (IKS) of practice—to create holistic solutions and industrial applications for agriculture and the health and industrial sectors.

2.1.1 Success stories of small-scale farmers with Bt-HT maize

Smallholder farmers make an important contribution to food production in South Africa, but they need better farming methods to boost their yields and incomes. The government, through provincial departments of agriculture, has introduced various schemes to uplift the agricultural and business skills of these farmers and to introduce them to productive tools and knowledge they can use to overcome the prevailing agronomic and climatic challenges. Thus AfricaBio—in collaboration with the Gauteng Provincial Department of Agriculture and Rural Development (GDARD)—have for the past 8 years worked with a number of emerging farmers and their communities in Gauteng to introduce them to the insect-resistant (Bt) and herbicide tolerant (HT) maize technology and to visually demonstrate the role of agricultural biotechnology in crop protection, so increasing yields and for income generation.

Just over 40 km north of Pretoria, in an area known as Masopane, is Onverwaght Farm, which is situated on a slope that overlooks open, vast carpets of green maize fields.

Here 35-year old Sophie Mabhena is living her farming dream. Mabhena grew up on this 385 hectare farm whose produce has paid for her schooling and the upkeep of her family. As a maize farmer, pest and weed control are key if Mabhena has to harvest a good crop that will ensure good income when she sells it to the millers down the road.

Mabhena grows the stacked GM maize, which has Bt and HT for insect resistance and weed control, respectively. Depending on the severity of the infestation, stalk-borer damage may reduce yields by 20 to 80 percent. Further damage to the cobs creates conditions for fungal infection of the maize. This in turn produces fungal toxins that can cause serious health problems when people eat the contaminated crop. "The stack maize is ideal for me because it has reduced my costs in terms of pesticides and the labour of weeding the field, but the major benefit has been the good yields and income from growing this improved variety of maize, " says Mabhena.

Although currently farming a small fraction of the family farm, Mabhena believes that the GM maize is an insurance against pests and weeds. She has never had a second thoughts about reverting to the planting of conventional varieties. For her, the way forward is to steadily increase the hectarage on GM maize so that she can sell more grain to millers. Her wish is to expand the farming venue which currently includes a thriving 75 herd of cattle, sheep, goats and chicken. She has also said that a small patch of vegetables has shown potential for the market.

"I am not going back to conventional maize; there is no way I can go back" Mabhena says. "I have found benefits in using the stack seed in terms of yields, and in five years I want to increase my hectarage to 100 hectares and become a top farmer. "

Mrs Sarah Buda learnt about the Bt maize technology in 2008 and is annually growing two hectares under Bt maize—since. She and her husband became maize farmers by accident, she says.

"I have always grown vegetables, but when I attended a presentation organised by the Gauteng Department of Agriculture and Rural Development on the opportunities offered by Bt maize, I was interested and I do not regret that I took up the offer to grow Bt maize, " Buda says.

Buda—who formerly rented out her land because she was unable to develop it—is setting her sights on using 140 hectares of the arable land in her 222 hectare Varkfontein farm, outside Pretoria. "But since I did training on farming Bt maize, I am more ambitious about commercial farming, because I am tired of being an emerging farmer. I want more income to develop my farm and to prove my worth as a farmer, " says Buda.

"While I rely on rain-fed maize, I have sunk boreholes to irrigate my vegetables; I will explore irrigating my maize too. "

During the first year, Buda planted GM maize. She realised such a good crop that a demonstration field day was held at her farm to show other farmers the benefits of Bt maize.

"For me Bt maize has been an advantage over conventional maize, because there has been no stalk borer in my field and there has been no need to use pesticides, " says Buda. She also laments that "People have complained about GM maize and worry about the impact on health, but we have cooked and eaten GM maize and nothing happened. Many people have also eaten the flour from GM maize. " The future plan is to have the entire farm under Bt maize says Buda,Who is also interested in growing GM soya beans. "I am encouraging other farmers to adopt this technology as we have realised good profits in growing it—because farming is a business. We need money. What do you do with a crop that does not give you good returns?"

Using Round Up ready seed has helped Buda deal with the challenges of weeds, but is also exploring what technologies are there for her to also control the weeds in her vegetable plot.

For Motlatsi Musi, another Bt maize farmer, biotechnology in agriculture could not have come at a better time than now. "When I experienced Bt maize for the first time in 2005, I got married to the idea because when I compared it with the 43 years I have spent in conventional agriculture, I realised that my practices like the use of pesticides used to affect me negatively", says Musi who farms in FunValley, Olifantsvlei, outside Johannesburg. "Then I did not have the tools, but I love the Bt seed technology because it came with a tool. The GM maize has given me 34 percent better yields than my conventional maize. "

Musi said the difference for him was that with planting a hectare of conventional maize and a hectare of GM maize, he would spray more pesticide on the former and none at all on the Bt maize.

"Depending on how I calibrate my planter, in my case I get 7 tonnes of maize per hectare and put out 55 000 plants. As farmers we need to make money, even though at times the market price for our produce is never guaranteed. "

"My future plan is to keep my silos full and the country's silos full—not only with Bt maize, but also with a range of grains. "says Musi. "I want to continue producing more maize, but have to work around the issue of seed availability. "

Musi, who also does pig and livestock farming, sells his Bt grain to commercial farmers. He has been able to put his son through university and has invested in better equipment for his farm with the proceeds of his Bt maize.

2.1.2 Issues

In South Africa, two challenges are identified in the development and adoption of GM crops:

1)*Public-funded research has not reached the commercialisation stage*:Biotechnology R&D in South Africa currently suffers from a lack of adequate funding and coordination. However, there is some indication that the government intends to look at biotechnology as one method to solve many of the current social, medical and economic problems. It is hoped that under the new bio-economy strategy—IKS, the manufacture of goods and chemicals, as well as the production of medicine and vaccines will receive greater attention and attract investors into investing more into biotech research and development.

2)*Propagation of misinformation and myths about GM crops*: The anti-GM movement is gaining ground in South Africa, and is *propagating refutable myths in five main areas*:

- ►*GM-derived food safety*—it has not been proven that GM crops and food are safe for human consumption. This concern has been expressed since GM crops were first commercially grown in 1996 in the USA, and since 1997 in South Africa.
- ►*Effects on small-scale farmers and seed control by multinational corporations*—the use of GMO will push out the small-scale farmer in favour of mass production and make them captive to the multinational seed companies. This view overlooks the fact that every farmer has a choice of what he or she plants.
- ►*Development of "superbugs" and "super-weeds"*—use of GMOs will stimulate the development of antibiotic-resistant "superbugs" and herbicide-resistant "super-weeds" that will require the use of increasingly poisonous chemicals.

- ► *"Contamination" of other plants*—the DNA of GM crops could mingle with the DNA of other plants.
- ► *Long-term risks*—the long-term risks of GMOs have not been adequately identified and managed. As a result, the anti-GM groups propose the mandatory labelling of all GM-derived ingredients, and have been putting much pressure on food manufacturers and retailers to source non-GM food products. There is significant scientific consensus that food derived from GM crops poses no greater risk than conventional food.

2.1.3 Recommendations

South Africa has 17 years of demonstrated experience in GM cultivation. The country has a robust regulatory system, and could play a leading role in biosafety training and communication in the region.

There is also a need for more voices advocating the use of the technology and for the identification of champions. Those in support of the technology—e. g. scientists and farmers—attest to the benefits of using GM crops. Argument in favour of GMO cultivation is that genetically modified plants have greater disease resistance and bigger yields, and there is significant scientific consensus that food derived from GM crops poses no greater risk than conventional food. No reports of ill effects from eating GM food have been proven in the human population. There are also environmental benefits associated with GM crops. Some GMO cropsare "designed" with a built-in resistance to insect pests, and these plants need fewer pesticides—making them a greener choice for farmers, than non-GMO crops that require pesticides. Plants can also be genetically improved to grow in poorer soils, colder temperatures, drier climates, and other less-than-favourable conditions.

2.2 Malawi

Malawi prides itself as one of the few countries in African with a functional biosafety regulatory system. The country signed the Cartagena Protocol on Biosafety on 24th May 2000 and ratified it in February 2009. In line with the requirements of the Protocol, the Malawian parliament enacted the Biosafety Act in October 2002. The Act provides for an institutional framework for its application—consisting of a National Biosafety Regulatory Committee(NBRC), reviewers, inspectors and a Biosafety Registrar. The Department of Environmental Affairs (EAD)—as the national competence—is responsible for regulation of biotechnology, which entails receiving and reviewing applications for activities with genetically modified organisms, and issuing licenses or permits. The EAD hosts the NBRC.

A national biotechnology and biosafety policy was approved by theMalawi cabinet on 26th June 2008. In the Malawi biotechnology and biosafety policy, there is a separation of roles and responsibilities of government—as well as R&D and other service-delivery institutions. The mandate for promoting and developing biotechnology in Malawi is vested in the National Commission for Science & Technology (NCST). The NCST hosts the National Biotechnology Committee, which is responsible for promoting biotechnology, public awareness, and coordination of biotechnology research and development.

The Ministry of Agriculture & Food Security has established its institutional biosafety committee (IBC), which is known as the Agricultural Biotechnology and Biosafety Committee (ABBC). It is technically and financially supported by the Ministry of Agriculture & Food Security.

It has been proposed by stakeholders that a Malawi Biotechnology and Biosafety Consortium (MBBC) be formed to advance the role of biotechnology and biosafety—for the improvement of livelihoods. The Consortium membership would include policy makers, scientists, private-sector leaders, civil-society organisation leaders, and government officers in their individual capacities—as well as public and private stakeholder agenciesfrom the health, agriculture, environment, and trade and industry sectors, amongst others. The overall goal of the MBBC would be to act as a unified body of stakeholders to support the safe and sustainable utilisation and economic development of biotechnology, for national development and socio-economic transformation.

2.2.1 R&D

In 2009, the Lilongwe University of Agriculture & Natural Resources (LUANAR) (formerly the Bunda College of Agriculture) submitted an applications forconfined field trials (CFTs) for cotton.

On 4th January 2013, Malawi joined South Africa as the second country in Southern Africa to carry out confined field tests of Bt cotton. Malawi successfully conducted its first-ever CFT for Bt cotton at LUANAR, which is located on the outskirts of the capital Lilongwe. The trial results showed more boll worm attack on the non Bt cotton than on the Bt cotton, and the yield was higher from Bt-cotton plots than from non Bt-cotton plots. The high yield was attributed to increased boll number per plant—rather than increased boll size. Analysis indicated that the economic benefits of growing Bt cotton were 50% higher than for conventional cotton. Permission has been obtained to repeat this CFT at research stations in cotton-growing areas like Chikhwawa, Salima and Karonga.

2.2.2 Issues

Regulatory hurdles: Although Malawi succeeded in field testing its first GM crop under confinement, it took almost two years (7th October 2011) for the trial to be approved by the Department of Environmental Affairs. The regulatory system in Malawi is still young and emerging, and therefore requires support to augment its capacity—in order to handle the influx of the CFT/commercialisation dossier it will have to handle in the coming years.

Anti-GM activism: Malawi is at acritical phase in the development of Bt cotton—with the planting of multi-locational CFTs. It can be expected that the increased publicity given to these trials will spur the anti-GM lobby to become more active and vociferous. This needs to be countered with a rapid response and greater public awareness. This is a task that could be undertaken by independent organisations established from a public/private partnership.

Furthermore, government officials need to be supported and supplied with the correct information, while the government must assure its citizens that only GM crops that are considered safe to human health and the environment—will be approved for general use.

2.2.3 Recommendations

Areas that require attention include:

- ►Support for the NBRC in biosafety communication.
- ►Training for members of the Agricultural Biotechnology and Biosafety Committee (ABBC), in order to serve as a team of scientific safety reviewers and to strengthen their capacity to conduct risk assessments.
- ►Training for the Biosafety Registrar, institutional biosafety committee members, and members of the NBRC—for their roles and responsibilities as biosafety regulators. Training for inspectors for monitoring and compliance is also needed.
- ►Facilitating attendance of the Biosafety Registrar and members of the NBRC in a functional biosafety committee meeting of another country.
- ►Increase the level of public awareness of GMOs.
- ►To establish and maintain the MBBC as a mouthpiece for the support and sustainable utilisation and economic development of biotechnology in Malawi.

2.3 Kenya

Kenya was the first country in the East African Community (EAC) to draft biosafety regulations and guidelines through the National Council for Science and Technology Act—in 1998. The country signed the Cartagena Protocol on Biosafety on 15th May 2000 and ratified it on 24th January 2002. The Biosafety Act was enacted in 2009 as the legal framework necessary to regulate agricultural biotechnology. This was followed by the publication of implementing regulations in August 2011—which opened the way for the commercialisation of GM crops. The focus then shifted to establishing the infrastructure and processes which are essential for an effective and functioning biosafety system.

Kenya's institutional biosafety framework—as outlined in the Biosafety Act 2009—revolves around the National Biosafety Authority (NBA), an agency whose mandate is to act as the coordinating institution on matters relating to the safe development, transfer, handling and use of GMOs. Operations of the NBA are supervised by a Board of Management that was appointed in April 2010. This board is composed of representatives from relevant government ministries, supporting regulatory agencies, scientists, farmers, and private sector and consumer organisations. The board makes the final decision on behalf of the government of Kenya with respect to agricultural biotechnology. The NBA has so far only handled applications for contained and confined use of GMOs.

2.3.1 R&D

Despite the current ban on GM products, R&D continues. CFTs are currently ongoing for Bt cotton, virus-resistant cassava, biofortified cassava, drought-tolerant maize (WEMA), virus-resistant sweet potato, and insect-resistant maize for Africa (IRMA). Most of these activities are being carried out by the Kenya Agricultural Research Institute (KARI), in collaboration with international research institutions.

2.3.2 Issues

Governance challenges: In November 2012, Kenya's president, Mwai Kibaki, imposed an immediate ban on GM imports and products in Kenya—based on the discredited Seralini study released by a French university in September 2012. This study linked cancer in rats to the consumptionof GM foods. Since then, Kenya has experienced a bottleneck at the port of Mombasa for maize shipments into the country, while they are evaluated against existing GM-related rules. At present, attempts are being made to have this ban lifted.

Small-scale farmers will also be denied access to improved GM crop varieties which are currently under confined field trials.

2.3.3 Recommendations

- ►The most current pressing issue is to repeal the ban imposed on the import of GM products.
- ►To convince the government to repeal the current ban on GM products.
- ►To train regulators and to develop the required regulatory infrastructure and processes for the anticipated commercialisation of GM crops currently under confined field trials, and for the importation of GM products.

2.4 Uganda

Uganda started drafting its biosafety regulations under the Uganda National Council for Science and Technology (UNCST) in 1998 to 1999. The country signed the Cartagena Protocol on Biosafety on 24th May 2000. As a signatory to the Cartagena Protocol on Biosafety, Uganda is obligated to institute the requisite policy, and legal and administrative provisions for the safe adoption and utilisation of modern biotechnology. As a step towards implementing a National Biosafety Framework, Uganda passed the National Biotechnology and Biosafety Policy in 2008. An Act to operationalise this Policy has been drafted—but still needs parliamentary approval.

In the absence of explicit legislation, Uganda has been operating within provisional arrangements in order to regulate the application of modern biotechnologies. The interim biosafety regulatory system is coordinated by the UNCST—which has defined a framework for research involving GMOs. However, the enactment of the law will enable a more unified approach to biosafety in the development and application of modern biotechnology. The Ministry of Finance, Planning and Economic Development (MFPED) and the Uganda National Council for Science and Technology (UNCST) are responsible for the bill.

2.4.1 R&D

Uganda has an impressive list of GM crops under research and development (see Table 2). Most of the biotechnology research activities are carried out by local scientists at the National Agricultural Research Organisation (NARO) and through international partnerships. The research aims to address challenges such as diseases and insect attacks, drought stress, and malnutrition.

2.4.2 Issues

Biosafety Bill: A law is required before the improved varieties under CFT can be made available to farmers. But the passage of the Biosafety Bill into law remains a challenge in Uganda, after 16 years. The GM projects will be ‘stuck’ at the field-trial stage, without ever progressing to release.

Anti-GM activism: The groups lobbying against the passage of the Biosafety Bill have been successful in polarising the debate and stalling the political process, —without an opportunity for a balanced and substantive conversation about the risks and benefits of the technology. The national debate is preoccupied with largely invalid fears fuelled by campaigns of misinformation and scaremongering.

2.4.3 Recommendations

- ►Support for the passing of the National Biosafety Bill.
- ►Support and training for the National Biosafety Authority Post the CFT activities, which will lead to general release (commercialisation) of approved GM crops for Uganda.

2.5 Ghana

Ghana acceded to the Cartagena Protocol on Biosafety, on 30th May 2003. Initially, Ghana’s biosafety regime was driven by Legislative Instrument (LI 1887: Management of Biotechnology in Ghana)—passed in May 2008. This has since been superseded by the Biosafety Act assented to in December 2011. The Act established the Ghana National Biosafety Authority (NBA), following which a Board has been constituted and is awaiting official inauguration. The country is also currently working on developing implementing regulations to help operationalise the Act. In the interim, the NBC is fully functional and has been reviewing and making biosafety decisions on applications submitted, and other related matters.

Ghana has made good progress in building an active and functional biosafety regulatory system—in collaboration with various stakeholders. The Biosafety Secretariat is currently functional and is coordinating biosafety activities in Ghana. Technical assistance and capacity building in administrative handling and review of applications, effective performance of regulatory functions, and upgraded skills in biosafety decision-making has led to a successful review of four CFT applications.

The NBA has been instructed by the responsible government ministry to issue guidelines for the implementation of the Biosafety Act (ABNE, 2013).

2.5.1 R&D

The Crop Research Institute (CRI) in Kumasi and the Savannah Agricultural Research Institute (SARI) in Tamale are conducting confined field trials following a successful review of four CFT applications. These are: Bt cotton, Pod-borer (*Maruca*) resistant cowpea, nutrient-enhanced sweet potato, Nitrogen-use efficiency,Water-use efficiency and salt-tolerant (NEWEST) rice.

2.5.2 Issues

Regulatory capacity: Training is needed in the development and implementation of standard operating procedures, handling and review of biosafety applications, adoption of best practices for safe conduct, and inspection and monitoring of CFTs.

Anti-GM activism: The discussions on GMO' in Ghana is also preoccupied with invalid fears fuelled by anti-GM campaigns of misinformation and scaremongering.

2.5.3 Recommendations

- ►Provide strategic guidance, technical support and capacity-building efforts to ensure that the nation's biosafety regulatory system is fully functional.
- ►Finalise and implement a communication strategy to help deepen biosafety knowledge and awareness among the key actors and stakeholders—on issues of biosafety and biotechnology. This will help promote effective public participation in GMO decision-making.
- ►Help Ghana to ratify and implement the Nagoya-Kuala Lumpur supplementary protocol on liability and redress.

2.6 Burkina Faso

Burkina Faso signed the Cartagena Protocol on Biosafety on 24th May 2000. Act No.005-2006/AN was passed on 17th March 2006, to regulate safety matters in Burkina Faso. With a functional biosafety system in place, the country approved the commercial release of Bt cotton in 2008, after completion of six years of field trials. Burkina Faso thus became the third country in Africa to grow GM crops—following South Africa and Egypt.

In 2010, the government of Burkina Faso started to review and revise the national biosafety law. The process was concluded in December 2012, with the adoption of the revised law by the National Assembly.

2.6.1 R&D

Research and development activities are being conducted at the Agricultural Research Institute (INERA-Farakoba) responsible for conducting confined field trials of biotech crops, the Muraz Centre which is working on GM mosquitoes, and the International Centre for Livestock research (CIRDES).

Five GM events have been approved in Burkina Faso. These include insect-resistant cotton (Bt) which has been commercialised since 2008, herbicide-tolerant cotton (Roundup Ready Flex), Pod-borer resistant cowpea under confined field trial.

2.6.2 Issue

African model for Biotech adoption: The Burkina Faso experience is a working model of how biotechnology can be successfully introduced in Africa. It shows that with strong government support, biotechnology can overcome challenges in legal frameworks, technocratic bureaucracy, and can be supported and sustained by business models that link the private sector to small and medium-sized producers in developing countries. Other cotton-producing countries in the region—like Mali and Benin—could benefit as much as Burkina Faso.

2.6.3 Recommendations

- ►Following the adoption of the revised law, implementing regulations need to be drafted.
- ►Further to the adoption of the revised law, the national agency needs to strengthen its biosafety communication plan.
- ►Support is needed to build capacities on the inspection of CFTs and post-release monitoring and evaluation.

3 Conclusion

Genetically modified (GM) crops are now the fastest adopted crop technology in the history of agriculture. However, their adoption in Africa has been limited. Only South Africa, Burkina Faso, Sudan and Egypt have commercialised GM crops to date. Nevertheless, various projects are in the field to test new GM varieties for African farmers—ranging from drought-resistant maize to varieties of banana, cowpea and sweet potato with resistance to pests and disease, and nutritionally-enhanced cassava and sorghum.

The introduction of GM crops requires a functioning biosafety regime to assess and manage potential risks. As modern biotechnology progresses, it is important to develop science-based and practical biosafety measures—including research and the vast pool of current scientific knowledge—with experts of these regions. Unfortunately, few sub-Saharan African countries have fully functional biosafety legal frameworks, while the remaining countries have only interim biosafety frameworks or none at all. The drafting of regulations sufficiently stringent to protect against genuine ascertainable risks, and the ability of decision-makers to discern the appropriateness of data necessary to adequately conduct a risk assessment ("nice to know" vs. "need to know"), all have considerable consequences. For example, too much information often confuses decision-making, diverts time and efforts from the more important task of identifying potential risks—thereby slowing the procedure and increasing associated costs. Thus, despite the considerable investment in R&D and human-capital development, the potential of GM in Africa is not being realised. So far, no GM trait developed has reached the hands of African farmers.

The concerted misinformation onslaught on GM crops does not serve the interests of Africans. Proliferation of misinformation about GM crops has led to confusion and fear, and thus the slow adoption of the technology. There's a need for science-based and factual biotech information dissemination and discussion—to educate people about the new innovations in agriculture that are helping farmers in other countries to meet their food-security needs. There is also a need for stakeholders—especially scientists, journalists and policy makers—to come together and to discuss openly and share factual information about the science of biotechnology, and how it can be harnessed in a responsible way for the benefit of all. Farmers should be given the choice and the right to use new agricultural tools that will help them address a plethora of challenges they face in the field: including pests, diseases, drought, flooding, and excessive heat.

It is suggested that the AU and national governments should be more supportive of the need for sub-Saharan countries to evaluate the benefits of GM crops to increase food security and poverty alleviation on the continent.

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