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EFFECTS OF GENETICALLY MODIFIED (GM) MAIZE ADOPTION IN SMALL SCALE FARMS ON CROPPING SYSTEMS OF THE EASTERN CAPE PROVINCE, SOUTH AFRICA

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ABSTRACT

Genetically modified (GM) crops are being promoted to ensure agricultural productivity and food security to keep pace with the ever-growing global population and food demand. In as much as agricultural technological advancements are crucial, there is need to strike a balance with agrobiodiversity for sustainable farming. Surveys were conducted in five municipal districts of the Eastern Cape Province to determine GM-technology adoption effects on maize cropping systems, agronomic practices and farmers' perceptions of production constraints. Interviews of 232 farmers, independent (IF) 22.4% and government sponsored (GCP) 77.6%, revealed a wide variation in agronomic practices amongst them. Results indicate significant differences on the maize cropping systems practiced by the Eastern Cape small scale farmers. The majority (81.7%) of interviewed small scale GCP farmers produce maize as a monocrop, under dryland (91.7%) through conventional tillage practices (100%). In contrast, IF farmers practiced maize sole cropping (34.6%), under dryland (90.4%) through conventional tillage practices (86.5%). There were significant differences between the two farmers' groups on crop mixture used (p=0.00), crop rotations (p=0.02), choice of maize varieties (p=0.00) and fertiliser use (p=0.00). Demographic and farm characteristics, type of land cultivation, production constraints, pest problems and pest management practices are discussed. The findings suggest the need to devise a system that will improve compatibility of GM-maize technology and traditional farming practices to ensure sustainable farming and food security for the resource poor farmers. The government support schemes seeking to enhance agricultural productivity need to equip farmers with the necessary versatile farming skills.

Contribution/Originality: This study investigated the impact of the GM-technology adoption African small scale cereal based cropping systems, agronomic practices and farmers' perceptions of production constraints. The findings suggest the need to devise a system that will improve compatibility of GM-maize technology and traditional farming practices.

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most important staple crops in South Africa (DAFF, 2013). The maize industry in South Africa consists of a commercial sector and a non-commercial sector made up of small scale farmers (DAFF, 2013). Although the total number of small scale maize farmers in South Africa is unknown (DAFF, 2013) the main small scale maize production areas are located in the Eastern Cape, Limpopo, Mpumalanga and

KwaZulu-Natal Provinces (DAFF, 2013). It is estimated that 320 105 ha of white maize and 136 795 ha of yellow maize was cultivated by the non-commercial sector in 2012/13 (DAFF, 2013). The maize cultivated by the non-commercial sector constitutes only 5% of the total maize produced in the country (DAFF, 2013). The Eastern Cape is distinguished by the fact that all maize produced in the province is by the non-commercial sector (DAFF, 2013). Maize produced in the province constitutes approximately 55% of the total maize produced by the non-commercial sector in South Africa (DAFF, 2013). Yields of maize in the province are generally low averaging 1.8 t ha $^{-1}$, owing to the general steep topography, inherent poor infertile soils, drought conditions, poor cultivars and insect pest attacks (Fanadzo, 2012; Nel & Davies, 1999). The Eastern Cape government has undertaken robust approaches to support small scale farmers with a view to tackle food insecurity and poverty in the former homelands (Provincial Growth and Development Plan, 2004). Currently, the province is rolling-out the Cropping Programme support scheme being implemented under the auspices of the Eastern Cape Provincial Growth and Development Plan (PGDP) (Eastern Cape Rural Development Agency, 2013). This has got the same thrust as the previous government support schemes such as The Farmer Support Programme of the 1980s and The Massive Food Programme initiated in 2003 (Department of Rural Development and Agrarian Reform, 2014). Farmer participation in the Cropping Programme is on condition to pay 18% of the cost of production per hectare, with the government covering the 82%. Based on the availability of government funds, the Eastern Cape Rural Development Agency (ECRDA) appoints private service providers who buy the tallying inputs and also undertake mechanisation services including, ploughing, planting, fertilizer, insecticide and herbicide application on behalf of farmers (Eastern Cape Rural Development Agency, 2013).

One of the strategies being implemented to intensively expand and improve maize productivity by the small scale farms is the introduction of GM crops (Giller et al., 2011; Qaim & Kouser, 2013; Thierfelder & Wall, 2012). Genetically modified (GM) maize was first introduced to small scale farmers in Eastern Cape during the 2001/02 cropping season (Gouse., 2012). Cultivation of GM crops enhanced productivity through the incorporation of desirable traits that include pest resistance into selected varieties of maize, soyabean and cotton for insect resistance (Bt), herbicide tolerance (RR) and Stacked' trait (with Bt and herbicide tolerance traits in one seed) (Gouse, Pray, Kirsten, & Schimmelpfennig, 2005). GM technology enhance the actual yield of crops by, partly, mitigating the effects of "reducing factors" by enhanced plant protection from pests including insects, weeds and diseases (Van Ittersum et al., 2013). However, there were concerns that this could lead to genetic erosion and loss of biodiversity (Schmidt & Wei, 2006). Although the GM-maize technology introduced in small-scale farms has eased the stem borer and weed management constraints of farmers (James, 2012) concerns about potential adverse ecological effects still remain (Altieri, 2000; Gepts & Papa, 2003). Concern has been raised that the introduction of GM crops will decrease the overall genetic diversity within crop species because breeding programs will concentrate on a smaller number of high value cultivars (Gepts & Papa, 2003). Proponents of the technology, however, claim that the introduction of GM crops has had little effect on crop genetic diversity because of the widespread use of the trait in many breeding programs (Bowman, May, & Creech, 2003; Sneller, 2003). Several others (Ammann, 2005; Slabbert, Spreeth, Krüger, & Bornman, 2004; Swaminathan, 1998) claim that biotechnology represents a tool for enhancing genetic diversity in crop species through the introduction of novel genes. Studies by Jacobsen, Sørensen, Pedersen, and Weiner (2013); Jacobson and Myhr (2013) and Kotey, Assefa, Obi, and Van Den Berg (2016) revealed that area planted to the GM maize is rapidly increasing and this may have it impact on the small scale cropping systems.

Similar to small scale farmers elsewhere, Eastern Cape small scale farmers have preference for traits other than high yield, for example storability and yield stability (Jacobson, 2013). These farmers cultivate diverse open pollinated varieties of maize mixed with legumes and practice crop rotation to satisfy these requirements. Due to a strong focus on increasing yield however, these features preferred by small scale maize farmers are side-lined in the development of modern maize varieties (McCann, Dalton, & Mekuria, 2006). GM maize varieties currently cultivated by small scale farmers are therefore those designed for advanced agricultural markets and commercially

oriented large-scale farmers (Asefa & Van den Berg, 2009). As a consequence, currently commercialized GM maize varieties in Eastern Cape are based on few commercial hybrids that do not necessarily reflect the specific conditions of small scale farmer/s (Bailey, Willoughby, & Grzywacz, 2014). The original OPV maize and cropping systems in GM maize production areas are absent and are replaced with the use of patent-protected GM seeds by the Plant Breeders' Rights Act 1976 (No. 15 of 1976) and also regulated by the Genetically Modified Organisms Act (No. 15 of 1997) to follow a specific cropping practice. The adoption of GM maize in the Eastern Cape is significant and affects the agrobiodiversity, cropping systems and livestock, which help the small scale farmers to sustain themselves. These effects also require vast and careful research and constant monitoring, parallel to the spreading of the GM maize cultivation. This survey was conducted to evaluate the effects of GM technology adoption on farmers' traditional practices of utilising agrobiodiversity. The information gathered is essential for evaluating the impact of adopting agricultural technological advancements and the consequences thereof on sustainable small scale agriculture practices.

2. MATERIALS AND METHODS

2.1. Study Sites and Survey Methodology

Surveys were conducted in five of the six municipal districts of the Eastern Cape (EC), which were purposively selected on the basis of the level of maize production in the province. Alfred Nzo, Amathole, Chris Hani, Joe Gqabi and O.R Tambo districts were visited from July 2014 to January 2016, Figure 1. The Government cropping programme of cultivating GM-maize was free for all maize farmers in the Province to participate. Hence, to be part of the government cropping programme (GCP) or to remain an independent farmer (IF) without government sponsorship was individual farmer's decision. The study grouped the interviewed farmers into two: those who accepted GM-maize cultivation (GCP) and those who are not involved (IF). Differences in farmers' perceptions, cropping system and crop production practices between these groups are considered as differences resulting from adoption of GM-maize.

No accurate records exist on the number of small scales that purchase GM seed or the area of land cultivated to GM maize seed in small scale systems in the Province (Gouse, 2012). The total number of small scales in the Province is also not known (DAFF, 2013). Number of farmers interviewed was decided based the number of registered farmers under the government cropping programme and the estimates of their proportion to the total number of farmers in a district (information provided by extension agents). Attempts were made to interview at least 20% of the small scale farmers under the government cropping programme (GCP) and independent farmers (IF) without government sponsorship in all the studied districts.

A semi-structured questionnaire with closed and open-ended questions was used to extract information by interviewing a total of 232 farmers under the government cropping programme (GCP) (180 farmers) and independent farmers (IF) without government sponsorship (52 farmers). Government extension officers and farmer's village chairpersons assisted in the identification of the farmers under the government programme. Separate interviews were conducted targeting independent farmers. Questions presented to the respondents included the type of maize cropping system practiced, agronomic practices and perceptions of production constraints. The number of farmers interviewed per district varied from a minimum of 21 in Chris Hani, 23 in Amathole, 43 in Alfred Nzo, 60 in Joe Gqabi to a maximum of 85 in O.R Tambo district. The differences were due to variation in number of maize producing farmers in the districts and accessibility of the farming community. Frequency counts and percentages were calculated based on the farmer response for each question asked. In instances when a farmer did not respond to a particular question, they were excluded in the calculation of the percentages. In cases of multiple response questions, percentages were calculated for each category. SPSS Version 24 statistical package was used to carryout Binomial regression analysis and Chi-square analysis. Independent sample t-tests were used to test differences between GCP and IF farmers' responses in relation to the cropping

system practiced and their perceptions. The multiple response variables were subjected to the Cochran's test and P-values were adjusted using the Bonferroni method. Differences were considered to be significant at the 5% level.
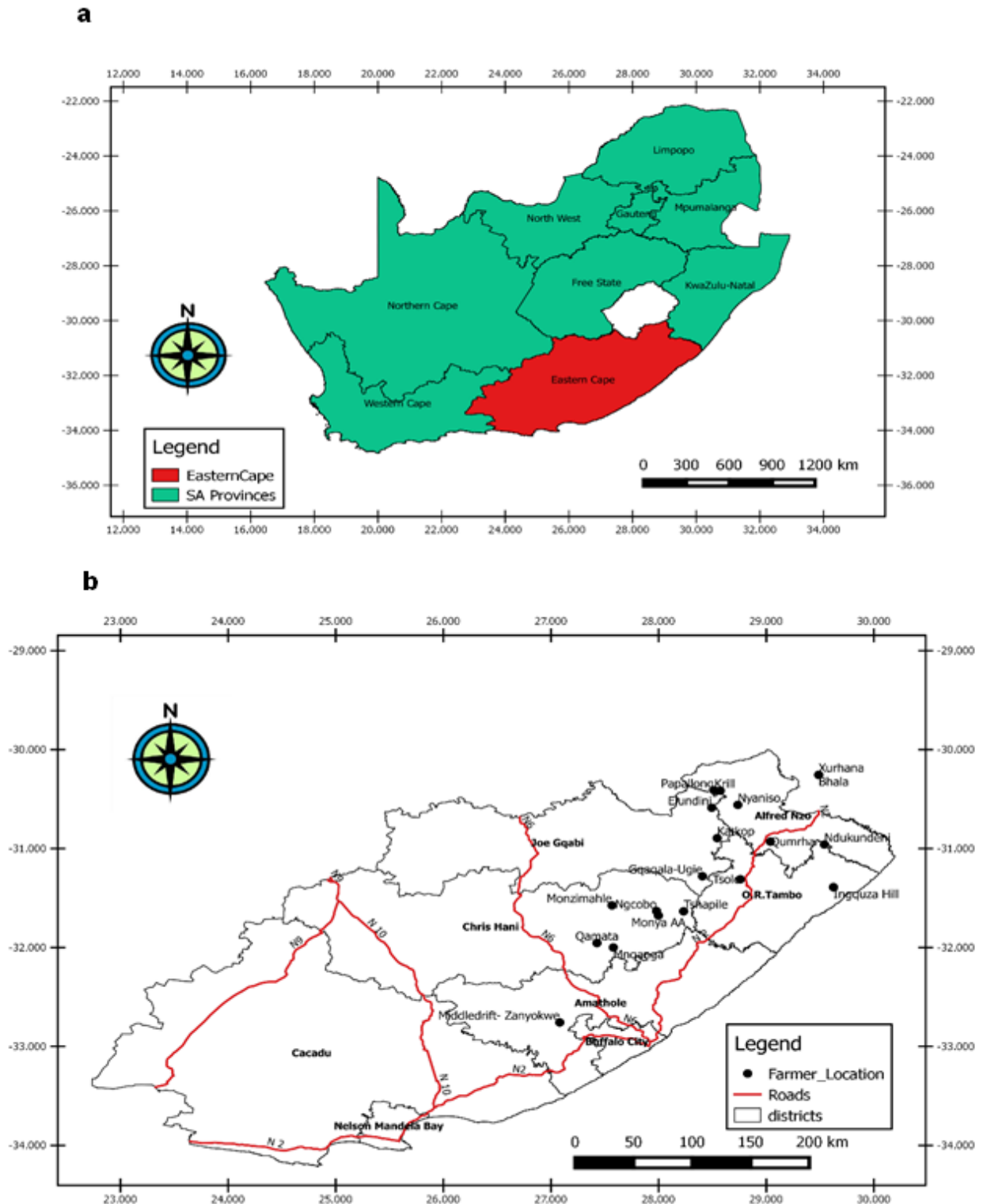
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Figure-1. Maps of Eastern Cape Province showing (a) the location of the province in South Africa (b) Localities where interviews were administered to maize farmers (Maps source: Survey coordinates and CSIR spatial data repository).

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3. RESULTS

3.1. Household and Farm Characteristics

Household heads of the two groups were slightly gender biased with 51.7% of GCP and 59.6% of the IF households were headed by males Table 1. There were no significant differences (p=0.31) on the household heads gender representation between the two groups. The age of the GCP household heads ranged between 27 and 82 years and the IF farmers' age ranged between 23 and 89 years. The average age of the farmers was 57.9 years for GCP and 56.3 years for IF farmers. There were no significant differences on the household heads' age (p=0.41), level of literacy (p=0.27) and family size (p=0.11) between the farmer groups. There were significant differences (p=0.05) on farm size holdings between the two farmers' groups with GCP having an average of 1.8 ha whereas IF farmers had an average of 2.8 ha. There were significant differences (p=0.05) on the proportion of the farm land allocated for maize production. The majority of GCP farmers (86.1%) allocated the whole farm land for maize production, whereas 75% of IF farmers allocated for the same. About 13.5% of the IF farmers allocated half of their farm land to maize production, whereas 3.9% of the GCP allocated the same Table 1.

Table-1. Household and farm characteristics of the two farmer groups (IF and GCP) in the five districts of Eastern Cape Province.

Variable	GCP (n=180)	IF (n=52)	Total (n=232)	t-test	P-value
Gender of household head (%)					
Male	51.7	59.6	53.4	1.03	Ns
Female	48.3	40.4	46.6		
Household head age (years)					
Average	57.9	56.3	57.6	0.83	Ns
Range	27-82	23-89	23-89		
Educational level (%)					
None	15.0	19.2	15.9	3.96	Ns
Primary	46.1	34.6	43.5		
Secondary	32.2	32.7	32.3		
Tertiary	6.7	13.5	8.3		
Family size					
Average	7.9	6.9	7.7	1.62	Ns
Range	1-30	2-16	1-30		
Family members age (%)					
0-17	22.2	31.0	23.8	1.83	Ns
18-50	23.0	17.2	22.0	0.77	Ns
Over 50	54.8	51.7	54.3	-0.62	Ns
Members helping in farming					
Average	2.7	2.8	2.7	-0.48	Ns
Range	1-11	1-14	1-14		
Farm size (ha)					
Average	1.8	2.8	2.1	-1.96	0.05*
Range	0.3-30	0.1-14	0.1-30		
Maize land allocation (%)					
25	1.1	0	0.9	1.98	0.05*
50	3.9	13.5	6.0		
75	8.9	11.5	9.5		
100	86.1	75.0	83.6		

The land tenure system of the interviewed farmers was largely communal, 90% (GCP) and 90.4% (IF) with only 9.4% and 7.7% of the GCP and IF farmers respectively, individually owning farms Table 2. The most common tool owned by both farmer groups was a hoe with 59.9% (GCP) and 30.4% (IF). However, there were significant differences (p=0.00) on the ownership of a matraca, knapsack sprayer, animal plough, animal planter and tractor and tractor mounted implements. Generally, more IF farmers personally owned farming equipment though some GCP mentioned having access to them through the support scheme Table 2. A knapsack, one of the equipment used in the control of pests, was owned by 21.1% of the IF farmers whereas 13.5% of GCP owned the same. Only 7.1% of

the interviewed GCP farmers had tractors as compared to 9.4% of IF farmers. Animal drawn ploughs and planters accounted for 24% and 11.7% from IF as compared to 9.4% and 9.8% respectively from GCP farmers Table 2. Maize farming experience ranged from below 5 years to over 20 years, with 46.2% (IF) and 60% (GCP) having over 20 years' experience growing maize Figure 2. The majority of the respondents acknowledged that maize farming was a practice they inherited from their parents so as to ensure food security and also as a feed source for their livestock.

Table-2. Household and farm characteristics of the two interviewed farmer groups.

Variable	GCP (n=180)	IF (n=52)	Total (n=232)	X²-value	P-value
Interviewed farmers					
Alfred Nzo	17.2	23.1	18.5		
Amathole	9.4	11.5	9.9		
Chris Hani	10.0	5.8	9.1	4.21	ns
Joe Gqabi	28.3	17.3	25.9		
O.R Tambo	35.0	42.3	36.6		
Land Tenure (%)					
Communal	90.0	90.4	90		
Individual	9.4	7.7	9.1	1.01	ns
Rented	0.6	1.9	0.9		
Equipment owned (%)					
Hoe	59.9	30.4	49.1	0.58	ns
Matraca	0.3	3.5	1.5	16.6	0.00*
Knapsack	13.5	21.1	16.2	40.47	0.00*
Tractor plough	7.1	9.4	7.9	10.98	0.00*
Animal plough	9.4	24.0	14.7	77.34	0.00*
Animal planter	9.8	11.7	10.5	12.09	0.00*

3.2. Farmers' Maize Production Practices

Under the cropping programme, inputs acquisition and major agronomic operations of land preparation, planting up to pesticide applications were carried out mainly by private contractors leaving little participation by the GCP farmers. A comparison between IF and GCP farmers showed some variations in the farming systems and the agronomic practices employed. The choice and use of maize varieties was significantly affected by farmers' adoption of the Cropping Programme (p=0.00) with GCP farmers heavily depending on mainly GM-maize (88.9%) and very few (3.3%) using OPVs Table 3. Almost 60% of the GCP farmers who planted GM seed used the stacked gene-BR (for both insects and weed control) while the remainder used RR trait with round-up resistance only. On comparison to IF farmers, conventional hybrids constitute 27% of the IF farmers seed requirement, with the majority (60%) relying on the relatively affordable OPVs. More GCP farmers used improved maize seed varieties which are largely GM seeds supplied through the input scheme, unlike the majority of IF farmers who use local traditional OPVs as seed. There were significant differences (p=0.02) on the farmers' maize production for the green market (to sale maize as green mealies). More IF (12.7%) farmers than GCP (5.1%) targeted the green market. However, there were no significant differences (p>0.05) on the intended use for grain and/or animal feed purposes. The majority of GCP (91.3%) and IF (82.5%) farmers produced maize for consumption. Only 3.6% and 4.8% of GCP and IF farmers respectively, produced maize for animal feed.
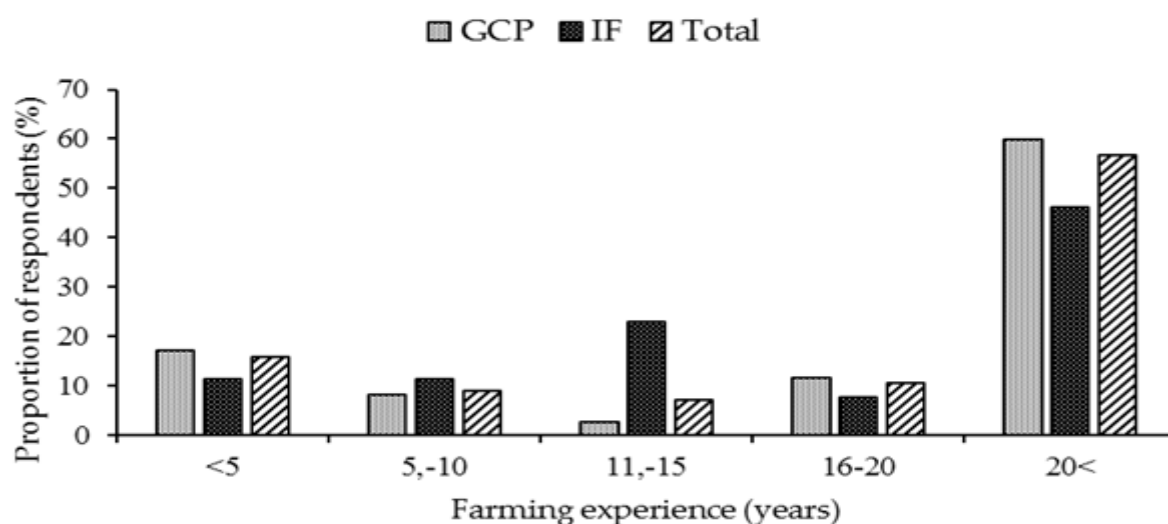
Figure 2. Farming experience (years) of the interviewed farmers of the Eastern Cape.

There were significant differences (p=0.00) on the land tillage practices by the farmer groups. All of the GCP (100%) farmers conventionally tilled the land as compared to 86.5% of the IF farmers. Mechanisation provision is a package of the support programme that GCP farmers are left with no option than to practice conventional tillage. Few (11.5%) of the IF farmers practiced minimum tillage with only 1.9% not tilling the land Table 3. Access to equipment, income availability and the need to practice conservation agriculture (CA) by some IF farmers was reflected in the different land cultivation practices. The majority of GCP farmers (81.7%) produced maize in a monocropping system which was significantly different (p=0.00) to 34.6% of IF farmers practicing maize monoculture. The majority of GCP farmers practiced maize monoculture principally due to the isolation legislative requirements and agronomic restrictions of growing GM maize, in the case of herbicide resistant (BR and RR) varieties (Monsanto, 2012; Van Ittersum et al., 2013). GM-maize in the GCP fields is planted in large fields which are either formed by bringing individual members' fields together or on community owned fields. Most of the IF farmers mentioned intercropping of beans and potatoes as a practice they inherited traditionally and also to ensure food security for the small scale farmers. A greater proportion of IF farmers (65.4%) practiced intercropping as compared to only 18.3% of GCP farmers who mixed maize with other crops Table 3. A quarter of IF farmers rotated maize with crops such as beans, potatoes and vegetables, as compared to a significantly (p=0.02) few of GCP (12.2%) farmers practicing crop rotations in their fields. Most GCP farmers did not rotate maize with other crops citing the lack of fencing around the fields, subsequent crop damage by freely grazing livestock after the maize season, erratic winter rains and the shortage of income to support any other crop than maize. The majority of GCP farmers (94.4%) practiced fallow during which livestock will be grazing in the fields, which were not significantly different (p=0.13) to 88.5% of the IF farmers practicing fallow Table 3. More (12%) of the IF farmers did not practice fallow during which they planted rotational crops as compared to 5.6% of GCP farmers.

The type of soil fertility supplements farmers used varied between the two groups. The majority of GCP farmers (76.1%) used inorganic fertilisers (basal, urea and LAN) in their fields, significantly different (p=0.00) as compared to 30.8% of IF farmers. Significantly (p=0.00) more of the IF farmers (38.5%) applied livestock manure in the fields as fertility supplements as compared to only 3.9% of GCP farmers. However, there was no significant difference between the GCP (20%) farmers to 30.8% of IF farmers who mentioned mixing of livestock manure and inorganic fertilisers before field application Table 3.

Table-3. Maize production practices by the interviewed GCP and IF farmers.

Variable	GCP (n=180)	IF (n=52)	Total (n=232)	X²-value	P-value
Maize varieties (%)					
GM	88.9	13.5	72		
Hybrids	7.8	26.9	12.1	49.07	0.00*
OPV	3.3	59.6	16		
Production purpose (%)					
Grain	91.3	82.5	89.2	5.45	ns
Animal feed	3.6	4.8	3.9	5.45	ns
Greenmarket	5.1	12.7	6.9	5.45	0.02*
Land cultivation (%)					
Conventional	100	86.5	97.0	24.99	0.00*
No tillage	0	1.9	0.4	24.99	ns
Minimum	0	11.5	2.6	24.99	0.00*
Irrigation (%)					
No	91.7	90.4	91.4	0.08	ns
Yes	8.3	9.6	8.6		
Crop mixture (%)					
Mixed	18.3	65.4	28.9	43.49	0.00*
Sole	81.7	34.6	71.1		
Rotations (%)					
No	87.8	75.0	84.9	5.14	0.02*
Yes	12.2	25.0	15.1		
Fallow practice (%)					
Yes	94.4	88.5	93.1	2.25	ns
No	5.6	11.5	6.9		
Fertiliser use (%)					
Organic	3.9	38.5	11.6	56.10	0.00*
Inorganic	76.1	30.8	65.9	56.10	0.00*
Both	20.0	30.8	22.4	56.10	ns

3.3. Farmers' Perceptions of Production Constraints

Farmers listed a total of 10 constraints hampering maize production. Insect pest attacks and weeds were the widely-mentioned constraints with 24.8% and 21.1% responses respectively, which were followed by drought (19.7%) and the lack of fencing (15.3%) Figure 3 The delays in mechanisation and inputs supply, hail, snow, theft and the lack of marketing structures were among the other challenges mentioned by farmers Figure 3.
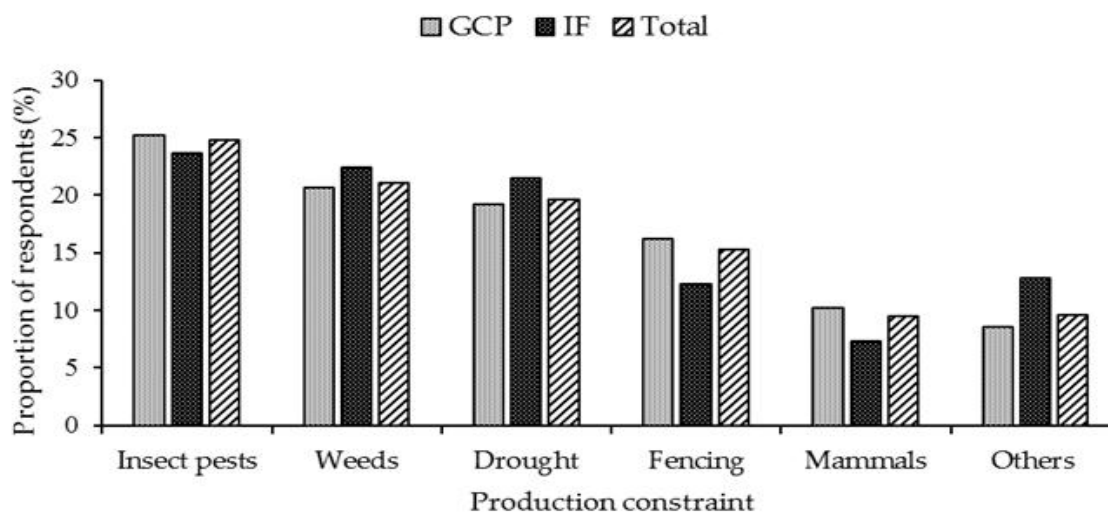

Figure-3. Farmers' perceptions on maize production constraints.

On comparison, there were significant differences on how farmers perceived various variables to be challenges upon maize production Table 4. About 20.7% of GCP farmers mentioned weeds to be of importance in their maize fields, which were significantly different (p=0.02), as compared to 22.4% of IF farmers Table 4. The adverse effects of drought were regarded by 19.2% of GCP farmers as a major constraint in maize production, which was significantly different (p=0.02) to 21.5% of the IF farmers who perceived the same. Although they had large responses, there were no significant differences (p>0.05) on the proportion of farmers who perceived insect pests, the lack of maize fields fencing and destruction by mammals as constraints Table 4. Farmers are aware of the common insect pests attacking maize. Significant differences (p=0.00) were on how GCP (13.1%) farmers and 18.1% (IF) farmers perceived bollworms to be problematic in maize production Table 4. About 28.3% of the GCP farmers perceived stalk borers to be of a major setback in maize production. In contrast, 22.9% of the IF farmers considered stalk borers to be of importance which were not significantly different (p=0.15) to GCP farmers. One of the major crop establishment insect pests, cutworms, were mentioned by 26.8% and 22% of GCP and IF farmers, respectively to be of importance. However, there were no significant differences (p=0.23), on how the two farmer groups perceived them to be of importance Table 4.

Table-4. Interviewed farmers' production constraints, common insect pests and control practices.

Variable	GCP (n=180)	IF (n=52)	Total (n=232)	X^2 value	P-value
Production constraints (%)					
Insect pests	25.2	23.7	24.8	1.18	Ns
Weeds	20.7	22.4	21.1	5.51	0.02*
Drought	19.2	21.5	19.7	5.23	0.02*
Fencing	16.2	12.3	15.3	2.40	Ns
Mammals	10.2	7.3	9.5	1.29	Ns
Others	8.6	12.8	9.6	7.21	0.01*
Common insect pests (%)					
Stalk borer	28.3	22.9	26.8	2.09	Ns
Cutworm	26.8	22.0	25.5	1.43	Ns
Aphids	6.4	7.0	6.6	1.85	Ns
Bollworms	13.1	18.1	14.4	19.13	0.00*
Pollen beetles	7.5	8.4	7.8	2.41	Ns
Others	8.3	6.2	7.8	0.04	Ns
Control practice (%)					
Pesticides	54.2	37.0	49.9	21.98	0.00*
GM seed	34.0	6.5	27.0	35.79	0.00*
Cultural	8.4	28.7	13.5	42.83	0.00*
No control	3.4	27.8	9.6	73.78	0.00*

There were no significant differences on how the interviewed farmers perceived aphids (p=0.17) and pollen beetles (p=0.12) on their importance in maize production. Both farmer groups employed various control strategies to combat pest attack. There were significant differences (p=0.00) on how farmers employed pesticides and GM maize in the control of pests. The GCP farmers relied heavily on pesticides (54.2%) and GM maize (34%) in the control of pests. In contrast, only 37% of the IF farmers employed pesticides to control pests Table 4 and Figure 4. Greater proportion of GCP than IF farmers applied chemicals and planted GM maize as strategies of pest management. Pesticide application was based on a calendar schedule and the majority of interviewed farmer's sprayed carbamate (carbaryl) for the control of stalk borers, cutworms and bollworms. Glyphosate-based herbicides were applied for the control of weeds and some farmers used actellic dust for the control of storage insect pests. The majority of GCP farmers planted GM maize (Bt gene) intended for the control of stalk borers with a small proportion growing roundup-ready (RR) varieties for easier control of weeds in the fields. Cultural methods of pest management were significantly (p=0.00) and largely employed by IF (28.7%) than GCP (8.4%) farmers. Some of the IF farmers cited that chemicals were expensive and out of reach for them. Farmers employed cultural pest control

through field sanitation, wood ash and livestock meat fat on maize crops to attract natural enemies in the control of stalk borers and bollworms.
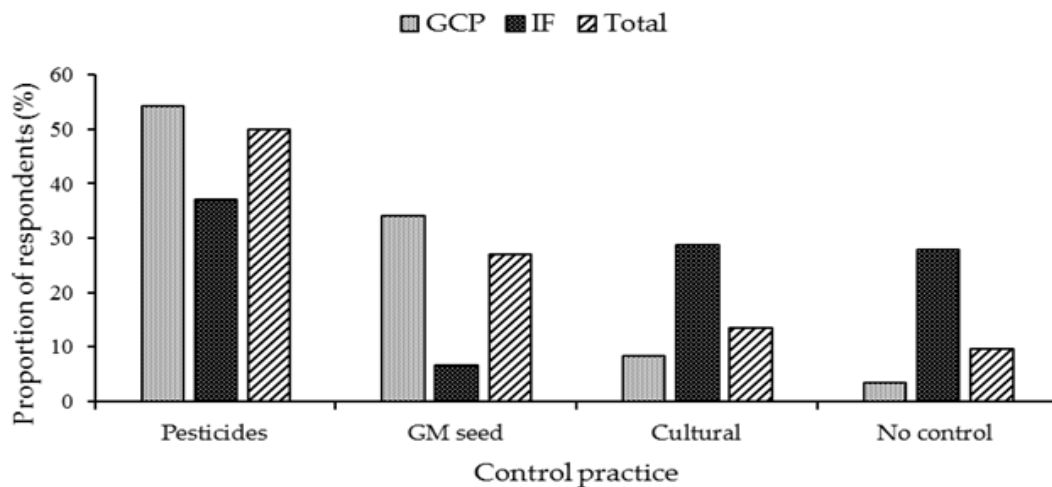

Figure-4. Pest control practices of the interviewed farmers.

4. DISCUSSION

New technological advancements are dependent on the farmer's age, expertise and level of education in that they will be able to evaluate innovation merits against traditional practices (Knowler & Bradshaw, 2007). Our results indicate that most of Government sponsored farmers are no more in their active age and this may have an impact on their decision to adopt the GM-maize technology. Studies show that planning horizons of farmers shrink as they age and their incentives for them to invest in the future productivity of their farms diminish (Daberkow & McBride, 2003; Marenya & Barrett, 2007). Moreover, most of these farmers (61%) attended only up to primary schools and therefore it is unlikely that they read and understand the information on the user guide for GM-maize production. Younger and educated farmers are more likely to adopt new practices that extension agents should be focused on recruiting young farmer for sustainable development and dissemination of the GM maize technology in the province (Adesina & Baidu-Forson, 1995; Brown & Venkatesh, 2005; Morris & Venkatesh, 2000).

As it is a case in other parts of Africa (Abate, van Huis, & Ampofo, 2000) IF small scale maize farmers in Eastern Cape still practice intercropping and crop rotations. These practices are known to keep insect pests at check (Abate et al., 2000; Altieri, 2000; Lithourgidis, Dordas, Damalas, & Vlachostergios, 2011). Crop mixtures of maize, Napier grass and silverleaf have been utilized in the push-and-pull system (Brush, 2000; Khan, Pickett, Wadhams, & Muyekho, 2001) and proved to be effective in the control of stem borers in maize in Kenya (Altieri, 2000). The rationale practice of diverse, economically viable crop rotations has also got the benefits of improving soil fertility, natural pest regulation and enhancing productivity (Altieri, 2000; Giller et al., 2011; Thierfelder & Wall, 2012). However, studies on the effects of intercropping and crop rotations in the management of stem borers and weeds in small scale farms of the province is lacking. Stem borer research in South Africa is focused on large scale farms that small scale maize farms in the province received very little research attention (Assefa, 2015; Kotey, Assefa, & Van den Berg, 2017). Research findings from large scale farms of the country and abroad are delivered to and tested in the small scale farmers' fields through extension system which is increasingly becoming inefficient due to declining public sector resources, the lack of farmer empowerment, and a lack of specialist staff in the sector (Kotey et al., 2017). This may be a setback, as it is a hindrance to proper understanding of locally critical maize production constraints and means to tackle them in small-scale farmers' fields.

Our results indicate that the promotion of GM maize production under the auspices of cropping programme has resulted in a change in the small scales cropping system. Although the study found no conclusive cause-and-effect evidence of GM maize production on cropping systems, there was a highly significant reduction in mixed

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cropping by GCP farmers who were into more monocropping and less crop rotation. The two major GM maize varieties (BR and RR) were the most widely grown by GCP small scale farmers as sole crops indicating their possible significant contribution for the change in cropping system recorded. Studies reported that GM crop production leads to agricultural intensification, systems which are typical of monocropping having low ecological diversity (Altieri, 2000; Jacobson, 2013; National Academies of Sciences Engineering Medicine, 2016). Diverse agroecosystems which involve viable crop rotations and wide crop mixtures have the benefit of nutrient cycling, natural pest regulation and ensuring food security especially for the resource poor small scale farmers (Erenstein & Laxmi, 2010; Songa, Overholt, Mueke, & Okello, 2002). The majority of the GCP farmers are growing maize in a monocropping system due to the legislative nature of GM crops. The implementation of the cropping programme is of the top-down scenario whereby the government outsource companies for the supply of inputs (seed, fertilisers and chemicals) on behalf of the farmers (Kotey et al., 2016). There is low participation by farmers in the choice of maize varieties; consequently, the GM (BR and RR) seed they are receiving through the cropping programme is deterring them from practicing crop mixtures in their fields. The success of new technological advancements is crucially based on the active participation of all stakeholders especially the intended beneficiaries. Technological advancements developed in situ tend to be viable because they allow beneficiaries to adapt and will perceive them socially acceptable and economically attractive (Abate et al., 2000).The advent of agricultural intensification, such as GM crop production, however, has been reported to lead to an intensive use of pesticides which have serious consequences on pests' resistance development, health and environmental issues (Abate et al., 2000). The GCP farmers interviewed admitted to practicing calendar sprays especially for insect pests, wrong calibration of chemicals and sometimes over application of herbicides with the intention to increase efficacy when the weeds are overgrown. Previous study conducted by Kotey et al. (2016) revealed that most of the extension personnel lack adequate training to effectively disseminate GM maize technology to small small scale farmers and that farmers are not well aware of the GM maize technology. Inappropriate farm management practices, including the continued application of insecticides on Bt maize varieties and ignorance in the basic farming operations are common (Kotey et al., 2016). These results concur with the study by Aliber and Hall (2012) which envisage that, there is need for training and field demonstrations for EC small mall scale farmers prior to introduction of new technologies to raise awareness of regulations and stewardship for compliance with the new technology.

5. CONCLUSIONS

The survey has highlighted the importance of devising and disseminating technologies, which suit the intended beneficiaries. The majority of interviewed farmers were old and conservative who would want to preserve their traditional farming practices. The farmer is left at loggerheads to compromise with adoption of new technology over traditional practices. Farming requires socio-economic input and support, so the small scale farmers are left with no choice than to take up the cropping programme because they cannot sustain farming on their own. This has got risk of development of farmer apathy and lack of ownership and responsibility for the farming operations. For a technology to be sustainable, it has to have a participatory approach so as to empower the farmer and instil a sense of ownership in them rather than a top-down approach. This will prevent the collapse of government support schemes intended for the farmers. There is need for continuous assessments of the consequences and risk thereof of massive dissemination of GM technology to small scale farmers.

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