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Major constraints limiting maize productivity in smallholder (SH) farming sector of sub-Saharan Africa

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Diseases and pests are among the major constraints limiting maize productivity in the smallholder (SH) farming sector of sub-Saharan Africa. The objectives of this study were therefore, to determine how SH farmers perceive and cope with diseases and pests, identify with farmers other constraints to maize production. Data were collected from three villages of KwaZulu-Natal (KZN) province in South Africa using surveys and participatory rural appraisal (PRA) methodology. Local maize varieties were further evaluated for disease resistance and grain yield potential at two locations in KZN. Cob rots, grey leaf spot (GLS), maize streak virus (MSV), northern leaf blight (NLB), phaeosphaeria leaf spot (PLS) and common rust were the main diseases identified by farmers, but their incidence was low and occurrence infrequent. More than 75% of the farmers did not control both insect pests and diseases, while the rest used chemicals or everyday household remedies for control. Stalk borers and cutworms were the most prevalent insect pests, where as drought, excessive rains, hail storms, and soil fertility were the most important abiotic constraints identified. Field trial results of local varieties indicated high yield potential and genetic variability for disease resistance to PLS, GLS, and NLB. These findings suggest that; if the main production constraints are addressed, farmers could realize high yields from their local varieties. Breeding opportunities, therefore, exist for incorporating resistance or tolerance to these stresses into the local varieties.

Key words: Maize, diseases, pests, constraints, breeding, smallholder farmers.

INTRODUCTION

Maize (*Zea mays* L.) is the most widely grown food crop in sub-Saharan Africa (SSA) and is produced on approximately 22 million hectares of land, which is about 15.7% of the land area grown to maize globally (Pingali and Pandey, 2001). The total annual maize production in SSA is estimated at approximately 34.4 million tonnes (Aquino et al., 2001). Statistics have also shown that out

of the 23 countries with the highest per capita consumption of maize as food in the world, 16 are in SSA and the production is dominated by smallholder (SH) farmers (Byerlee and Heisey, 1997).

In South Africa maize is grown throughout the country under diverse environments including both dry land and rain fed conditions (Du Plessis, 2003; Fanadzo et al.,

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2009). In the Southern African Development Community (SADC), South Africa is the main maize producer (Baloyi et al., 2012; South Africa.info, 2013), producing more than 10 million metric tonnes in 2011 (FAO, 2013). The maize in South Africa is grown commercially on large farms and on more than 12,000 small farms, primarily in the North-West, Mpumalanga, the Free State and KwaZulu-Natal provinces (SouthAfrica.info, 2013). Nonetheless, studies have indicated that South African small scale agriculture is characterised mainly by low maize productivity with yields ranging approximately from 1.8 to 3.5 t ha⁻¹ (Baloyi et al., 2012; Fanadzo et al., 2009). These yields are within the range of yields reported for the SH farming sector in the rest of SSA, which average 1.2 t ha⁻¹ against a potential of 7.0 t ha⁻¹ (Fanadzo, 2007; Pingali and Pandey, 2001), thus presenting a big challenge for researchers.

Amongst the major constraints limiting maize productivity are abiotic and biotic stresses (Vivek et al., 2010). These constraints vary among growing areas and between cropping seasons. For example, disease epidemics and insect pest outbreaks frequently occur as a result of the warm climate and/or high rainfall common to many maize production zones in SSA (Vivek et al., 2010). Several diseases are endemic to most SSA maize production areas and these include maize streak virus (MSV), grey leaf spot (GLS) (*Cercosporazeae-maydis* Tehon & Daniels), rust (*Puccinia sorghi* Schwein. and *P. polysora* Underw.), northern leaf blight (NLB) (*Exserohilum turcicum* Pass. Leonard & Snuggs), ear rots (*Fusarium* and *Diplodia*), head smuts (*Sphacelotheca reiliana*) and *Phaeosphaeria* leaf spot (PLS) (*Phaeosphaeria maydis*) (Bonga and Cole, 1997; Vivek et al., 2010). These diseases are often difficult to control since their occurrence year after year is less predictable because of their high dependence on weather. As a result, in favourable seasons with high rainfall, diseases also become more prevalent and damaging. The majority of small-scale farmers, in most cases, do not control the diseases due to limited access to pesticides. Therefore, the development of maize cultivars with enhanced levels of disease resistance and high abiotic stress tolerance will be sustainable and effective for increased maize yields, especially in the smallholder farming sector.

Although there are some commercial cultivars available with some level of resistance to some of these diseases, PLS disease in particular, has been increasing in incidence and severity over the years in a number of countries that include Kenya (Mwangi, 1998), South Africa and Zimbabwe (Derera et al., 2007), Cameroon (Carson, 1999), Uganda, Rwanda and Zambia (Sibiya, 2009). This trend towards increasing severity and incidence of PLS in the region (Carson, 2005; Derera et al., 2007; Vivek et al., 2010) is likely to cause significant damage on maize, as has happened in the past with diseases such as GLS (Huff et al., 1988; Ward et al., 1999). Grain yield studies conducted in southern and eastern

Africa reported losses due to PLS averaging 29 to 43% depending on the susceptibility of the maize cultivars (Sibiya et al., 2011). This demonstrates the potential PLS has of becoming a major disease, thereby threatening regional food security.

Furthermore, there has been a resurgence of NLB in major maize growing areas in SSA, with previously resistant cultivars succumbing to the disease (Bucheyeki, 2012). Vivek et al. (2010) also indicated that the incidence and severity of NLB had increased, especially in Southern Africa in the past 3 to 4 years. This increase has the potential of threatening maize grain productivity with a negative impact on food security. Maize GLS disease, on the other hand, is currently the most important foliar disease in SSA, causing yield losses around 10 to 25% annually (Menkir and Ayodele, 2005). Therefore, it is imperative that high priority research be given to these diseases in all the important maize production areas of SSA. To achieve this, it is essential to understand how smallholder farmers perceive the production constraints in their environments and what mechanisms they have in place to cope with some of these constraints. This will facilitate breeding relevant cultivars that meet the farmers' needs.

Participatory methods have been used to gather information on important traits, and in facilitating the targeting of breeding programmes for greater impact (Witcombe et al., 2005). Farmers can provide very important information on plant types, desired traits and insight into trade-offs they are willing to make among traits in designing cultivar types (Sperling et al., 2001). Therefore, if the farmers' priorities, needs and capacities are valued and better understood by researchers; appropriate and sustainable recommendations can be made and thus, increase chances of adoption of new technologies (Scoones and Thompson, 1994). The objectives of this study were therefore; (i) to assess farmers' perceptions on disease and insect pest problems in maize production (ii) to assess the yield potential and disease reaction of local varieties grown by farmers through researcher managed trials, (iii) to identify and analyse other key constraints to maize production and (iv) to determine farmers coping mechanisms for dealing with diseases and pests in a selected SH farming area of KwaZulu-Natal (KZN).

MATERIALS AND METHODS

Description of study area

The study was conducted in three villages, Obonjaneni, Busingatha, and Okhombe, in Amazizi Tribal Authority (29°22'E, 28°44'S) in the Northern Drakensberg of KZN Province in 2007 to 2009. The population in the villages is approximately 900 households in Obonjaneni, 700 in Busingatha and 1,000 in Okhombe (Krone, 2006). The area is characterised by an average annual rainfall between 700 to 800 mm and the rainy season lasts from September/October to March (Ngubane and Mudhara, 2009). While the area is classified as having above average agricultural

potential, the major drawback is the short growing season, cold winters and acidic soils which tend to reduce the agricultural potential (Krone, 2006).

Sampling procedures, participants and data collection

A structured survey and participatory methodologies were used to obtain characteristics of farmers in the villages. A total of 300 randomly selected households were included in the structured survey. Across the three villages, the farmers representing these households were 59% females and 41% males. Information was gathered through a questionnaire administered to the farmers by facilitators to enable participation of those who could not read or write. The questionnaire was pre-tested on a small sample of farmers from the area and staff from Farmer Support Group (FSG), an NGO based at the University of KwaZulu-Natal (UKZN), which works with farmers in Amazizi district. Based on the responses from this trial survey, adjustments were made to the questionnaire. Different maize varieties grown by the farmers, goals for maize production, average yields, perceived constraints to maize production, and other general information were obtained from this survey.

The participatory methodologies used included focus group discussions, matrix scoring and pair-wise ranking. In addition a visit to two farmers' fields was done. 45 farmers turned up for the group discussions (47% females and 53% males) resulting in two focus groups per village of ± 10 key informants each. The discussions were guided by two facilitators in the local language (isiZulu) and notes were written down in English on a flip chart. The discussions involved key informants made up of individuals who had great knowledge about the villages, the farms, crops and local conditions and problems in the district. The groups were a mixture of farmers who planted many crop varieties, farmers with a reputation for good workmanship, young and old farmers, and farmers with large or small land holdings. Farmers identified the "core problems or constraints" to maize production, listed them and ranked them according to the most important constraints. The facilitators used pictures showing disease symptoms and cards that had drawings representing various constraints to assist the farmers during the discussions.

Biotic stresses (insect pests and diseases)

Although farmers were not told during focus group discussions that the study focus was on diseases and pests, special attention was given to the prevalence of these stresses. The farmers listed the diseases and insect pests that occurred in their area and indicated which ones were problematic and difficult to control, whether they used any form of control or not and listed some of the control methods used. To validate whether the local varieties grown were susceptible or resistant to some of the major diseases that occurred in KZN, 10 maize seed collections from the farmers were evaluated over two seasons (2007/8 and 2008/9) at Cedara Agricultural Research Station [30°16'E, 29°32'S, 1130 m above sea level (a.s.l)] and one season (2008/9) at Baynesfield Estate (30°21'E, 29°46'S, 758 m.a.s.l) for grain yield and disease resistance. These two sites are 'hot spot' areas for most maize diseases. The 10 maize seed collections plus a Pannar seed Company hybrid (PAN67) used as a check were planted in a randomised complete block design (RCBD) with two replications per site in two row plots, 3 m long, with 0.75 m inter-row spacing and 0.3 m intra-row spacing. Plant population densities were about 44 000 per hectare in all the seasons. Two blocks of two maize hybrids that were susceptible to the main foliar diseases in the area were used as borders for the trials. Standard hand weeding and/or application of herbicides and fertilizers were followed at each site.

Severity for the foliar diseases was assessed from the first appearance of symptoms, based on visual assessment of the whole plot. A diagrammatic 1 to 9 modified rating scale (Reid and Zhu, 2005) for foliar diseases was used where; 1 = 0%, 2 = < 1%, 3 = 1 to 3%, 4 = 4 to 6%, 5 = 7 to 12%, 6 = 13 to 25%, 7 = 26 to 50%, 8 = 51 to 75% and 9 = 76 to 100% leaf area showing disease symptoms.

Data analysis

Statistical analyses of both quantitative and qualitative data were performed in SPSS Release 15.0 (SPSS Inc., 2006), Genstat 12th edition (Payne et al., 2009) and PROC GLM procedure in SAS 9.1 (SAS Institute, 2002). For exploring relationships; frequencies, descriptive statistics and analysis of variance (ANOVA) were computed for data collected in each village followed by mean comparisons between villages. Before subjecting the data to ANOVA, percentage data were transformed using square root transformation to normalize the data.

RESULTS

General crop production aspects

Maize is grown mainly for consumption. The average grain yield was significantly different ($P = 0.001$) in the three villages ranging from 0.2 to 5.7 t ha⁻¹, with an average across the villages of 1.0 t ha⁻¹ from land holdings with averaged 1.1 ha (Table 1). Different maize varieties which included hybrids, open-pollinated varieties (OPVs) and local landraces were grown by the farmers (Table 1). The majority of the farmers (77 to 97%) grew a local or indigenous variety (landrace) which they called "Natal-8-row" or "IsiZulu". Other collections included another local variety called "Doylanda" grown by about 5 to 10% and improved OPVs grown by 10 to 27% of the farmers. Farmers indicated that *Doylanda* was a hybrid between the local *Natal-8-row* and Pannar hybrids that were grown in the area. The most popular hybrids were Pannar hybrids. These were grown by about 27-39% of the farmers.

Important biotic stresses in Amazizi district

Farmers through the structured survey and during focus group discussions listed the problem insect pests and diseases that were important in their area (Table 2). From the structured survey, more than 70% of the farmers indicated stalkborer (*Busseolafusca*) and cutworms (*Agrotis* spp.) as the prevalent insect pests in Amazizi district. About 27% of the farmers indicated that, although the two insect pests were prevalent, they were not a problem, while more than 54% of the farmers singled out the two as problematic pests in the area. Only 1% of the farmers mentioned a disease with yellowish leaves as being problematic.

In contrast, during focus group discussions, with the aid of pictures showing disease symptoms, farmers listed a

Table 1. Meanvalues for land holding (hectares), goals for maize production, yields and proportion of farmers growing different maize varieties in Amazizi district (n = 100 per village).

Parameter	Village			Overall mean	P-VALUE ¹
	Obonjaneni	Busingatha	Okhombe		
Land holding and crops grown (hectares)					
Size of landholding	1.1	1.0	2.1	1.4	0.001
Size of cultivated land	0.9	0.8	1.9	1.2	0.001
Land for maize	0.8	0.8	1.8	1.1	0.001
2Reasons for producing maize and quantity produced (kg maize)					
Home consumption	1824.0	354.6	625.0	924.6	0.001
Livestock feeds	119.9	78.8	143.5	114.1	0.003
Sale	1410.0	-	61.5	482.9	0.018
Average yields (t ha ⁻¹)					
Mean	1.5	0.7	0.8		
Min	0.3	0.3	0.2		
Max	5.7	1.7	4.4		
3Varieties grown (% of respondents growing variety)					
Natal-8-row (IsiZulu)	77.0	90.0	97.0		
Doylanda	10.0	-	5.0		
Hybrids	33.0	27.0	39.0		
OPVs	18.0	10.0	27.0		

¹Probability values based on one-way ANOVA. ²Based on data from previous years. ³*Natal-8-row* or *IsiZulu* local or indigenous variety; *Doylanda*, a variant from *Natal-8-row*, which was a hybrid between *Natal-8-row* and some Pannar varieties that were grown in the area; Hybrids-Pannar hybrids; OPVs - Afric1, Kalahari Early Pearl, Nelson's choice and R0413.

Table 2. List of problem diseases and pests (proportion offarmers responding) from the three villages in Amazizi district (for structured survey, n = 100 per village).

Parameter	Structured survey			Mean	Focus group discussion		
	OBO ¹	BUS ²	OKH ³		OBO (n = 12)	BUS (n = 15)	OKH (n = 18)
Prevalent diseases and pests							
Yellowish leaves	1.0	-	-	1.0	Cob rots	Stalk borer	PLS
Stalk borer	71.0	74.0	78.0	74.3	PLS ⁴	GLS ⁶	Stalk borer
Cutworms	80.0	67.0	68.0	71.7	NLB ⁵	MSV ⁷	NLB
Other ³	46.0	40.0	46.0	44.0	Stalk borer	NLB	Rust
					Cutworms	Weevils	
						Cutworms	
Problem diseases and pests							
None	30.0	29.0	23.0	27.3			
Stalk borer	69.0	71.0	77.0	72.3			
Cutworms	69.0	53.0	42.0	54.7			
Weevils	6.0	2.0	-	4.0			
Other ⁸	10.0	18.0	25.0	17.7			

OBO¹ = Obonjaneni, BUS² = busingatha, OKH³ = okhombe, PLS⁴ = phaeosphaeria leaf spot, NLB⁵ = northern corn leaf blight, GLS⁶ = grey leaf spot, MSV⁷ = maize streak virus, other insects⁸ = red and black insects, white butterflies, rats, moles, ants, "mkhothane".

Table 3. Chemicals used by the farmers to control pests and diseases in the field and in storage in Amazizi district (proportion of farmers responding, n = 100 per village).

Parameter	Village		
	Obonjaneni (%)	Busingatha (%)	Okhombe (%)
No control	75	87	78
Planted early	3	2	2
Unknown chemical (pink, white or blue)	12	5	9
Stalkborer granules [Kombat, a.i. carbaryl (carbamate)]	5	10	12
Kemprin 200EC (a.i. cypermethrin)	3	-	-
Phostoxin tablets (a.i. aluminum phosphate)	3	-	1
¹ Jeyes fluid (carbolic acid) [with or without additives]	11	1	1
Blue death (a.i. carbaryl/permethrin) mixed with fertilizer	2	-	4
Malasol (a.i. mercaptothion)	2	-	-
² Other	13	3	11

¹Jeyesfluid is a general household disinfectant not registered as a pesticide, but used as one, ²Other (Paraffin + salt added to seed, salt added to manure (or fertilizer) and seed, pepper, salt and pepper, sunlight dishwashing liquid).

Table 4. Mean square (MS) values from combined analysis of variance for maize diseases and yield (tha⁻¹) for the farmers' maize seed collections from Amazizi evaluated at Cedara and Baynesfield Estate in 2007/8 and 2008/9 seasons.

Parameter		PLS	GLS	NLB	Common rust	Yield (t ha ⁻¹)
Source	DF	MS	MS	MS	MS	MS
Environment (Env)	2	187.88***	128.90***	211.01***	8.38***	1.81
Rep(Env)	3	1.62**	9.54**	1.17	0.08	1.81
Genotype	10	6.94***	13.96***	4.94***	0.24	7.62
Genotype*Env	20	3.53***	3.07	2.95***	0.30	2.93
Error	30	0.45	1.77	0.83	0.68	1.96

*, **, *** indicates the term is significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$, respectively. PLS = Phaeosphaeria leaf spot, GLS = Grey leaf spot, NLB = Northern corn leaf blight.

number of diseases that occurred in their areas. Farmers in Obonjaneni indicated cob rots, Phaeosphaeria leaf spot (PLS) and northern leaf blight (NLB) as the diseases that affected their crops and the two pests; stalkborer and cutworms. In Busingatha, stalkborer was mentioned again as the most problematic pest and the diseases listed were grey leaf spot (GLS), maize streak virus (MSV) and NLB. In Okhombe farmers listed PLS, stalkborer, NLB and common rust as diseases observed in the fields. The farmers further indicated that these diseases were not a big problem in the area as their incidences were low and their occurrences infrequent. Stalkborer and cutworms were the major problems in the area, but more than 75% of the farmers in the three villages did not control the pests or diseases. Three percent of the farmers indicated planting early to escape the diseases and pests. About 5 to 12% of the farmers who controlled the pests and diseases could not identify the type of chemical used (Table 3). Others utilized everyday household products such as dish washing liquid (soap), paraffin oil, salt, and pepper for control. The complete list of all the control options used by the

farmers is given in Table 3.

Evaluation of farmers' maize collections for disease resistance and yield potential

Results of the disease screening and grain yield potential of the farmers' collections are presented in Table 4. The genotypes and environments were all significant ($P \leq 0.001$) for PLS, GLS, and NLB diseases. For common rust, only the environments were significantly different ($P < 0.001$), but the genotypes were not. The yield of all the genotypes was not significantly different ($P > 0.05$). Means for diseases and grain yield for the different genotypes are indicated in Table 5. The Kalahari Early Pearl (KEP) variety was the most susceptible to PLS with scores ranging from 7.5 to 7.7, followed by *Natal-8-row* (NTL8) which had scores ranging from 5.3 to 6.3. The *Doylanda* (DL) variety was moderately susceptible to resistant with scores ranging from 4.7 to 5.7. The Pannar hybrid (PAN67) had a score of 5.0. Reactions to GLS

Table 5. Mean values for disease scores¹ and grain yield (t ha⁻¹) for the farmers' maize seed collections from Amazizi evaluated at Cedara and Baynes field Estate in 2007/8 and 2008/9 seasons.

PLS		GLS		NLB		Yield (t ha ⁻¹)	
Genotype	¹ Mean	Genotype	Mean	Genotype	Mean	Genotype	Mean
² KEP-2	7.7 ^a	DL-1	7.7 ^a	KEP-1	5.7 ^a	PAN67	8.58a
KEP-3	7.7 ^a	DL-2	7.0 ^a	KEP-3	4.7 ^{ab}	KEP-1	6.41b
KEP-1	7.5 ^a	NTL8-3	7.0 ^a	KEP-2	4.5 ^b	DL-1	6.37b
³ NTL8-1	6.3 ^b	NTL8-2	6.8 ^a	NTL8-1	3.3 ^c	NTL8-3	6.28b
NTL8-4	6.0 ^{bc}	NTL8-4	6.8 ^a	NTL8-3	3.3 ^c	NTL8-4	6.28b
NTL8-2	6.0 ^{bc}	PAN67	6.7 ^a	DL-2	3.3 ^c	KEP-3	6.21b
⁴ DL-1	5.7 ^{bcd}	NTL8-1	6.7 ^a	NTL8-4	3.3 ^c	DL-2	6.02b
NTL8-3	5.3 ^{cde}	DL-3	6.5 ^a	DL-3	3.2 ^c	NTL8-2	5.80b
DL-2	5.3 ^{cde}	KEP-1	4.5 ^b	DL-1	3.2 ^c	NTL8-1	5.31bc
⁵ PAN67	5.0 ^{de}	KEP-2	3.5 ^b	NTL8-2	3.2 ^c	KEP-2	4.80bc
DL-3	4.7 ^e	KEP-3	3.2 ^b	PAN67	2.5 ^c	DL-3	3.85 ^c
Mean	6.1		6.0		3.7		6.0
CV (%)	11.0		22.2		25.0		23.3
LSD(0.05)	0.8		1.6		1.1		1.6

¹Disease rating scale used (1-9), ²KEP – Kalahari early pearl, ³NTL8 – Natal-8-row, ⁴DL – Doylanda, ⁵PAN67– was used as a check and it is a hybrid (white) from PANNAR recommended for small-scale farmers. Means in each column followed by the same letter are not significantly different.

were also variable among the genotypes. The DL variety had scores ranging from 6.5 to 7.7 and was the most susceptible, followed by NTL8 which had scores from 6.7 to 7.0. The KEP variety was the most resistant to GLS with scores from 3.2 to 4.5. PAN67 was susceptible with a score of 6.7. Scores of NLB ranged from resistant to moderately susceptible. The KEP variety was moderately susceptible to NLB, whereas the other genotypes were resistant to moderately resistant with scores ranging from 2.5 to 4.7. Symptoms of the diseases were often found on the same plant or different plants. For the OPVs (NTL8, DL and KEP), not all the plants in a row were susceptible to the same disease. PAN67 had the highest yield of 8.6 t ha⁻¹, whereas yield for KEP variety varied from 4.8 to 6.4 t ha⁻¹, NTL8 from 5.3 to 6.3 t ha⁻¹ and DL from 3.9 to 6.4 t ha⁻¹.

Other farmers' perceived maize production constraints in Amazizi district

There were significant ($P < 0.001$) differences in the farmers' responses for different constraints (Table 6). Farmers listed about 23 production constraints and overall, drought was the top constraint across the three villages, followed by heavy rains, storms, soil fertility, and weeds, insects, and diseases. In addition, the farmers listed the features they considered when classifying seasons as good or bad (Table 7). About 50 to 90% of the farmers characterised bad seasons as having either excessive, continuous rains, too many overcast days, drought during flowering and grain filling, hail, storms or

heavy winds. Pest and diseases were ranked fifth and sixth. Unavailability of seed of other varieties or not enough seed were not important constraints to the farmers as they were only ranked number 17 and 18. Not enough money for inputs was mentioned by only 8% of the farmers and ranked number ten.

DISCUSSION

Despite more land being allocated to maize, yields across the three villages were highly variable, ranging from a minimum of 0.2 to 5.7 t ha⁻¹ depending on the variety grown. The low yields observed in these villages were comparable to yields reported by Pingali and Pandey (2001) for most smallholder farming sector in SSA which averaged below 1.2 t ha⁻¹ against a potential of 7.0 t ha⁻¹. Fanadzo (2007) also reported maize yields averaging 1.8 t ha⁻¹ in Eastern Cape Province of South Africa. Low yields in most SSA have been attributed to factors such as: the majority of farmers being located in marginal areas with highly variable and stress-prone conditions, thus indirectly forcing them to rely on low-input and low-risk cropping systems (Banziger and de Meyer, 2002; Reeves and Cassaday, 2002). However, in this study, although the farmers are located in an above average agricultural potential area (Krone, 2006), results indicate that they relied mostly on low-input farming due to lack of capital, and this could have contributed to the low yields. Results from the researcher managed evaluation trials using the maize seed collected from the farmers in Amazizi district confirmed that the varieties grown by

Table 6. Farmers' perceived maize production constraints (proportion of farmers responding, n = 100 per village).

Characteristic	Village			Mean	Rank ^b
	Obonjaneni	Busingatha	Okhombe		
Drought	9.6 (92.0) ^a	8.7 (76.0)	5.8 (34.0)	8.1 (67.3)	1
Heavy rains	6.7 (45.0)	7.5 (57.0)	5.3 (28.0)	6.5 (43.3)	2
Storms	8.5 (73.0)	5.7 (33.0)	3.5 (12.0)	5.9 (39.3)	3
Soil fertility	7.0 (49.0)	4.5 (20.0)	5.8 (34.0)	5.8 (34.3)	4
Weeds	4.4 (19.0)	5.3 (28.0)	7.1 (50.0)	5.8 (32.3)	4
Insects	5.3 (28.0)	7.1 (51.0)	4.0 (16.0)	5.5 (31.7)	5
Diseases	5.0 (25.0)	3.7 (14.0)	3.2 (10.0)	4.0 (16.3)	6
Wrong planting time	2.0 (4.0)	4.8 (4.0)	3.7 (14.0)	3.5 (13.7)	7
Uncontrolled Livestock	2.0 (4.0)	2.0 (4.0)	4.0 (16.0)	2.8 (8.0)	8
Soil erosion	1.0 (1.0)	4.0 (16.0)	3.2 (10.0)	2.7 (9.0)	9
Not enough money for inputs	1.0 (1.0)	3.2 (10.0)	3.6 (13.0)	2.6 (8.0)	10
Poor land preparation	2.0 (4.0)	2.8 (8.0)	2.4 (6.0)	2.4 (6.0)	11
Wrong fertilizer type and (or) quantity	1.4 (2.0)	3.0 (9.0)	2.6 (7.0)	2.4 (6.0)	11
Scattered cattle	1.7 (3.0)	1.7 (3.0)	2.2 (5.0)	1.9 (3.7)	12
Water logging	1.0 (1.0)	1.4 (2.0)	2.2 (5.5)	1.6 (2.7)	13
Shortage of ploughing lands	1.7 (3.0)	1.4 (2.0)	1.4 (2.0)	1.5 (2.3)	14
Stony lands	1.0 (1.0)	1.7 (3.0)	1.7 (3.0)	1.5 (2.3)	14
Acidic soils	1.7 (3.0)	1.0 (1.0)	1.0 (1.0)	1.2 (1.7)	15
Lack of training in farming	2.0 (4.0)	0.0 (0.0)	1.4 (2.0)	1.1 (2.0)	16
Too much snow	2.4 (6.0)	0.0 (0.0)	0.0 (0.0)	0.8 (2.0)	17
Unavailability of other varieties of seed	1.4 (2.0)	0.0 (0.0)	1.0 (1.0)	0.8 (1.0)	17
Not enough seed	0.0 (0.0)	1.0 (1.0)	1.0 (0.0)	0.7 (0.7)	18
Baboons	1.0 (1.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.3)	19
Overall mean (transformed)				3.0	
LSD(0.05)				2.0	

^aData transformed (square root transformation). Values in parenthesis are the untransformed percentages. Ranking based on transformed means. ^bThe lower the rank, the more important the constraint.

Table 7. Definition of good and bad seasons according to the farmers in Amazizi (proportion of farmers suggesting the characteristic).

Good Season	N = 300 (%)	Bad Season	N = 300 (%)
Timely rains – especially in October, for timely planting of crops	4.0	Late rains – delays planting	4.0
Good distribution of rain throughout the season	99.3	Heavy excessive or continuous rains	77.3
Enough sunlight	50.3	Too many overcast days	50.3
Moderate weather – not too hot, cold or windy	2.3	Drought, especially during flowering and grain filling stages	98.3
		Hail storms and heavy winds	65.6
		Snow before harvesting	2.7
		Too many insects	1.3

these farmers had high yield potential. Yields obtained ranged from 3.8 to 8.6 t ha⁻¹. Efforts should therefore be made to address the production constraints in the area that may be contributing to the low yields realized by farmers in these three villages. In addition the results showed the existence of breeding opportunities for

increased yields in the local maize varieties.

Diseases and insect pests were not ranked highly in most of the cases. In this study only 1% of the farmers indicated a disease with yellowish leaves through the structured survey. Odendo et al. (2002) in Western Kenya and Mukanga et al. (2011) in Zambia made similar

observations that diseases were always ranked low on the farmers' perceived constraints list. It appears the symptoms of diseases are mostly confused with damage from abiotic stresses and insect pests and the farmers are also unable to assign the damage they observed on plants to individual factors as most of the elements occurred together (Mukanga et al., 2011). In this study, almost all the farmers classified stalk borer damage as a disease not insect damage. Farmers were able to recognize diseases after being shown pictures of various disease symptoms. Although they listed the diseases they had observed in their fields, the farmers indicated the diseases did not occur frequently and did not cause any significant yield losses. This confirms the observation made by Vivek et al. (2010) that most diseases have been reported to be difficult to control because of their occurrence which is less predictable every season. Some of the farmers indicated they planted early to escape diseases and pests and this was also the reason why they preferred early maturing varieties.

Stalk borer and cutworms were the most prevalent pests and farmers used various methods to control these pests. However, despite the prevalence of these two pests, the majority of farmers did not use any form of control. This was mainly due to lack of resources. Control included chemicals and everyday household products including dish washing liquid (soap), general disinfectants such as Jeyes fluid (carbolic acid), spices (pepper), salt, and paraffin oil. Most of these products have been found to be effective against a number of pests and diseases in gardens and in storage (FAO, 1999). For example, Rondon et al. (2006) indicated that dish washing liquid was effective against aphids and spider mites. Black and red peppers were effective against a number of grain storage pests (Ashouri and Shayesteh, 2010; FAO, 1999).

Disease and yield evaluation of the maize varieties collected from the farmers demonstrated clearly that, although some of the varieties were susceptible, high levels of genetic variability existed within the different varieties, especially in the OPVs (NTL8, DL and KEP). This demonstrated the non-uniformity of OPVs in general as they are broad populations with many parents (Setimela et al., 2006). This genetic variability within the varieties could be exploited in breeding for disease resistance, by selecting resistant plants from the population. The KEP variety was susceptible to PLS, but resistant to GLS and moderately resistant to NLB. On the other hand, NTL8 was susceptible to moderately susceptible to PLS, susceptible to GLS and resistant to NLB. The DL also gave varying reactions to the three diseases. There was a highly significant genotype x environment interaction. This was a result of different levels of disease in the two seasons and the two locations. Cedara Research Station had high PLS and GLS disease pressure in both seasons and high pressure for NLB in 2008/9 season, whereas Baynes field Estate had high GLS pressure in 2008/9 season. The varieties also

showed high potential for grain yield as the yields obtained in the evaluation trial were much higher than what the farmers obtained from their own plots. The variability in yield and disease reactions indicated that it was possible to select for high yield and disease resistant genotypes from these varieties. This implies that, if the other production constraints were addressed and farmers produced maize with the recommended rates of inputs, they could realize high yields and thus, reduces the gap that exists between their yields and potential yields.

Of the 23 production constraints listed by the farmers, drought was ranked highest across the three villages, followed by heavy rains, storms, soil fertility and weeds, insects, and diseases. According to the farmers' definition; drought meant poor distribution of rain during the season, especially poor rains during flowering and grain filling stages. Frequent heavy excessive rains, hail storms and heavy winds were indicated as a characteristic of a bad season. The rainfall in the area has been reported to be characterized by thunderstorms and intermittent dry spells (Ngubane and Mudhara, 2009). Not enough money for inputs was only ranked number ten, although most of the farmers had indicated that they were not growing hybrids because the cost of seed and other inputs such as fertilizers was high. One would have, therefore, expected this constraint to be among the top constraints. The reason could be that farming in this area is more oriented towards subsistence and is based on low inputs. Very few farmers in the area cultivated large acreages for sale, thus there was no incentive in investing money into crop production.

Conclusions

Less than 40% of the farmers planted their fields with hybrids, or improved OPVs. Diseases and pests were not ranked highly as constraints. Most of the farmers did not apply any chemicals to control the diseases and pests, with some planting early or using everyday household products for control. The local varieties exhibited high yield potential and genetic variability for disease resistance that can be exploited in breeding programmes. Abiotic stresses (drought, heavy rains, storms and soil fertility) were the top four constraints faced by the farmers. Breeding opportunities, therefore, exist for breeding varieties resistant or tolerant to these abiotic stresses and to raise yields of the local varieties.

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