Evaluation of Regional On-farm Variety Trials in Eastern and Southern Africa 2011

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The International Maize and Wheat Improvement Center, known by its Spanish acronym,CIMMYT® (www.cimmyt.org), is an international, not-for-profit research and training organization. With partners in over 100 countries, the center works to sustainably increase the productivity of maize and wheat systems to ensure global food security and reduce poverty. The center's outputs and services include improved maize and wheat varieties and cropping systems, the conservation of maize and wheat genetic resources, and capacity building. CIMMYT belongs to and is funded by the Consultative Group on International Agricultural Research (CGIAR)(www.cgiar.org) and also receives support from national governments, foundations, development banks, and other public and private agencies. CIMMYT is particularly grateful for the generous, unrestricted funding that has kept the center strong and effective over many years.

The Drought Tolerant Maize for Africa (DTMA) Project is jointly being implemented byCIMMYT and the International Institute of Tropical Agriculture (IITA), and is funded by the Bill & Melinda Gates Foundation and the Howard G. Buffett Foundation. The project is part of a broad partnership involving national agricultural research and extension systems, seed companies, non-governmental organizations (NGOs), community-based organizations (CBOs), and advanced research institutes, known as the DTMA Initiative. Its activities build on longer term support by other donors, including the Swiss Agency for Development and Cooperation (SDC), the German Federal Ministry for Economic Cooperation and Development (BMZ), the International Fund for Agricultural Development (IFAD), and the Eiselen Foundation. The project aims to develop and disseminate drought tolerant, high-yielding, locally-adapted maize varieties and to reach 30–40 million people in sub-Saharan Africa with these varieties in 10 years.

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Abstract

In 2006, the Drought Tolerant Maize for Africa (DTMA) project was initiated with the aim of improving maize germplasm in the drought prone mid-altitude regions of eastern and southern Africa (ESA). Through this project eight hybrids and four open-pollinated varieties (OPVs) were developed through multi-location trials under optimal (well fertilized and well-watered conditions), rainfed, low soil nitrogen and managed drought stress environments. To validate the performance of the new germplasm against commercially available germplasm and farmer-preferred varieties, a series of trials were conducted across 49 farmers' fields in eight countries in 2010/11 seasons in ESA. Trials were un-replicated and conducted under farmer management, with farms considered blocks in a randomized complete-block design. Average trial yields ranged from 0.7 t ha^{-1} to above 8 t ha^{-1}. Trials were divided into two categories based on yield levels; high yielding trials >=3 t ha^{-1} (n = 30 trials) and low yielding trials < 3 t ha^{-1} (n = 19 trials). Broad sense heritability of high and low yielding trials was 0.80 and 0.62 to 0.94 and 0.61, respectively, indicating that highly repeatable means can be estimated from un-replicated on-farm trials in ESA. The best new DTMA hybrids out-yielded the farmers' own varieties by more than 35% and 50% under low- and high-yield conditions, respectively, when compared to SC513, the most widely grown commercially hybrid available varieties in southern Africa.

Introduction

Recurring droughts provide a continuous challenge to smallholder farmers in eastern and southern Africa (ESA). The annual yield loss in maize due to drought is estimated between 15% and 90% depending on the stage when drought occurs (Edmeades et al., 1995; NeSmith and Ritchie 1992). Losses in maize production are predicted to increase with climate changes as temperatures rise and rainfall distribution patterns change in key traditional maize production areas of ESA (Lobell et al. 2008). Farmers in drought prone areas invest less in inputs such as fertilizers and improved seeds but plant large areas in the hope of improving food security.

The development, deployment and cultivation of drought tolerant (DT) maize varieties is a highly relevant intervention to reduce vulnerability, food insecurity and the damage to local markets accompanying food aid (Langyintuo et al 2008). While drought tolerance is a complex polygenic trait (Ribaut et al., 2002), conventional drought stress tolerance breeding has yielded significant dividends in maize (Bänziger et al., 2006). Conventional breeding for drought tolerance has resulted in gains of up to 144 kg ha^{-1} yr^{-1} in tropical maize when stress was imposed at flowering (Edmeades et al., 1999). In temperate maize, the rate of breeding progress has been estimated at 73 kg ha^{-1} yr^{-1} for mild stress (Duvick, 1997), 146 kg ha^{-1} yr^{-1} when the stress was imposed at the flowering stage, and 76 kg ha^{-1} yr^{-1} when the stress was imposed during mid-grain filling stage (Campos et al., 2004). In 1997, CIMMYT initiated a drought breeding program targeted at improving maize for the drought-prone mid-altitudes of southern Africa (Bänziger et al., 2006). Maize varieties were

selected in Zimbabwe using simultaneous selection in three types of environments, (i) recommended agronomic management/high rainfall conditions, (ii) low nitrogen stress, and (iii) managed drought. The breeding focus was on hybrids with open pollinated varieties (OPVs) being developed mainly as synthetics derived from elite inbreds, as a by-product of hybrid breeding. Elite hybrids and OPVs were tested and validated through regional testing network which included partners from National Agricultural Research Systems (NARS) and private seed companies in ESA. The first drought tolerant hybrids and OPVs adapted to ESA agro-ecologies were released in 1999 by NARS and private partners (Bänziger et al., 2006).

In 2006, CIMMYT initiated the Drought Tolerant Maize for Africa (DTMA) project targeted at improving maize for the drought prone mid-altitude regions of ESA drawing lessons from the successes in the development and scaling up of drought tolerant maize varieties. The objective of this study was to compare the best commercial varieties against new DT varieties developed under managed drought stress conditions.

Table 1. Characteristics of maize cultivars evaluated on farm trials in eastern and southern Africa

Varieties	Origin	Current and Old DT varieties	Vigour	Maturity group	Year of first release
ZM309	CIMMYT - SA	Current	OPV	Early	2008
ZM523	CIMMYT-SA	Current	OPV	Medium	2005
ZM627	CIMMYT-SA	Current	OPV	Late	
VP0717	CIMMYT-SA	Current	OPV	Late	
09SADVE-F2	CIMMYT-SA	Current	OPV	Medium	
ZM521	CIMMYT-SA	Old	OPV	Medium	2002
Pan53	PANNAR	Old	Hybrid	Medium	2006
Pris601	Pristine	Current	Hybrid	Medium	2010
CZH0928	CIMMYT-SA	Current	Hybrid	Early	
CZH0837	CIMMYT-SA	Current	Hybrid	Medium	
CZH0616	CIMMYT-SA	Current	Hybrid	Medium	2012
CZH0524	CIMMYT-SA	Old	Hybrid	Medium	2011
CZH0615	CIMMYT-SA	Current	Hybrid	Medium	
CZH0946	CIMMYT-SA	Current	Hybrid	Early	
SC403	Seed Co	SeedCo	Hybrid	Early	1997
SC513	Seed Co	SeedCo	Hybrid	medium	1999
SC627	Seed Co	Seed Co	Hybrid	Medium	1999
CKH08210	CIMMYT-EA	Current	Hybrid	Late	
CKH08205	CIMMYT-EA	Current	Hybrid	Late	
Farmers Variety	Various		Hybrids/OPVs		

Material and methods

This study was conducted on-farms in, Ethiopia, Kenya Tanzania, Malawi, Mozambique, Uganda, Zambia and Zimbabwe in 2010/2011 seasons (Figure1). New hybrids and OPVs were selected based on performance under optimal (well fertilized and well-watered conditions), rainfed, low soil nitrogen and managed drought stress environments (Table 1). Commercial hybrids, older OPVs and various farmer-preferred varieties were also included to allow current germplasm to be compared with improved germplasm in farmers' fields (Table 1).Trials were grown between November and April in southern Africa and April to August in eastern Africa. A randomized complete block design was used with each farm as a replication in each location. Each plot consisted of a six rows 8m long with crop spacing decided by the farmers following their normal practice. Trials were divided into two categories based on yield levels; high yielding trials >=3 t ha^{-1} (n = 30 trials) and low yielding trials < 3 t ha^{-1} (n = 19 trials). All trials were grown under rainfed conditions. Data was analysed using SAS (SAS 2011). For all analyses, farms were considered random while varieties were considered fixed factors. Broad –sense heritability (H^2) was estimated as the ratio of the genotypic variance (σ_g^2) to the phenotypic variance (σ_p^2) on variety mean basis.

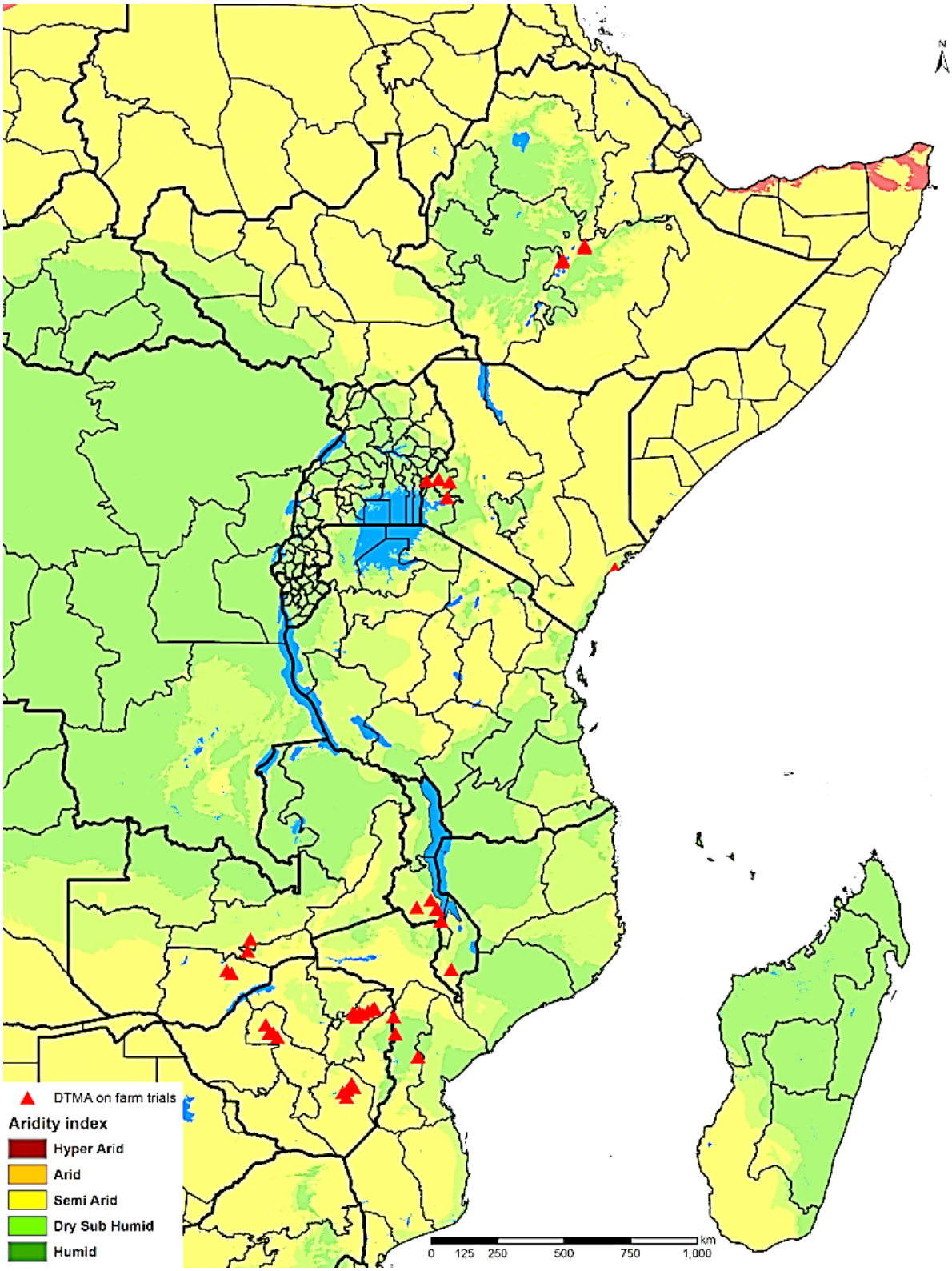

Figure 1. Sites of on-farm regional trials grown in eastern and southern Africa

Results

The trials results are presented in Table 2. The trials were divided into two categories, >=3 t ha^{-1} (n = 30 trials) which were classified as high yielding and < 3 t ha^{-1} (n = 19 trials) which were classified as low yielding (Table 2). The average grain yields across eastern and southern Africa ranged from 6 t ha^{-1} in high yielding trials to as low as 0.2 t ha^{-1} in low yielding trials. Hybrid CZH0616 was the best yielding DT hybrid for both high and low yielding trials across ESA. Open pollinated varieties ZM627 and 09SADVEF-2 were the best yielding across the two regions. These OPVs yielded better or equally to SC513 in both high and low yielding trials across the two regions, while the new DT hybrid yielded better than Pan53 which is one of the commercially available hybrids developed under managed stress but was released before the project started.

The best DT hybrid CZH0616 yielded about a 35% higher than SC513 under high yielding trials and more than 50% under the low yielding trials. The yield gap was wider under low input trials compared to high yielding trails which show that the project made more progress under stress conditions compared to optimum conditions (Fig 2&3).

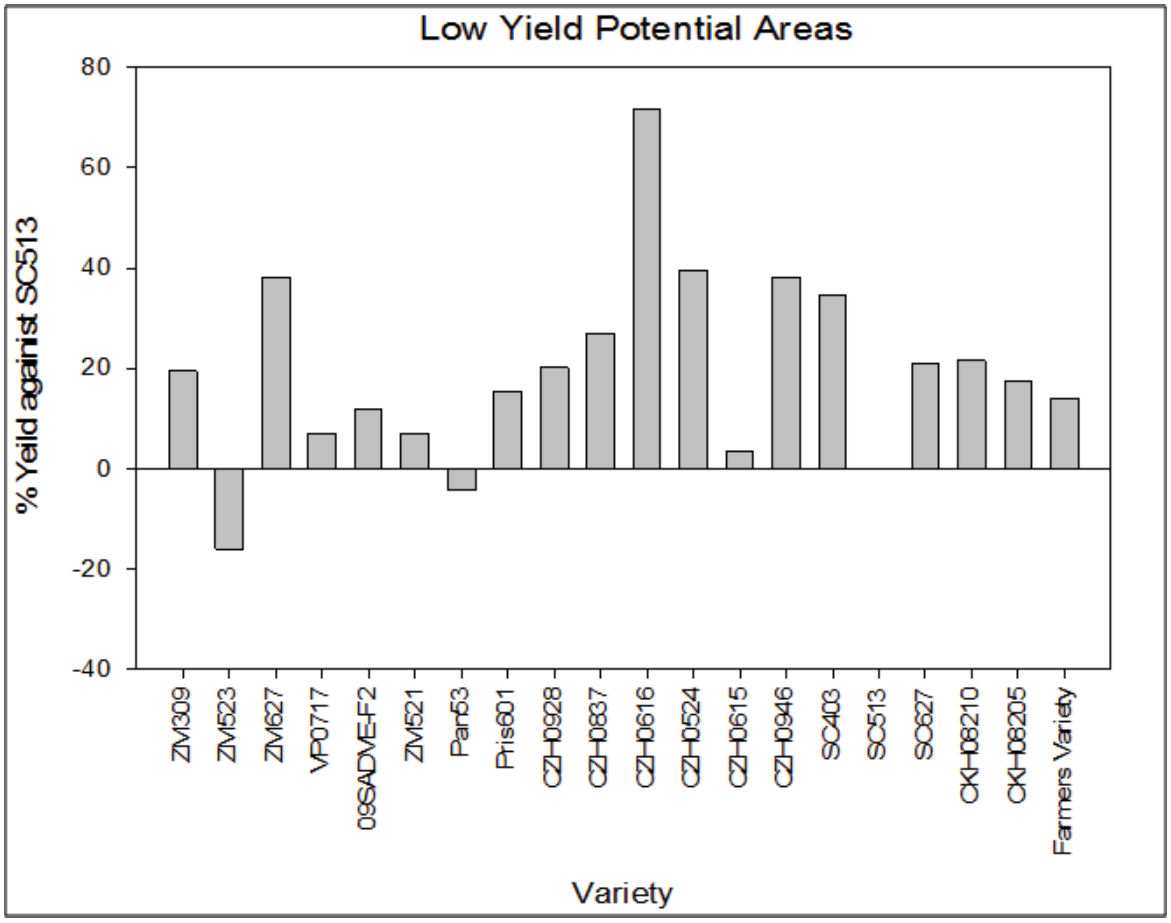

Figure 2. Per cent yield level against SC513 across eastern and southern Africa for trials yielding above 3 tons/hectare

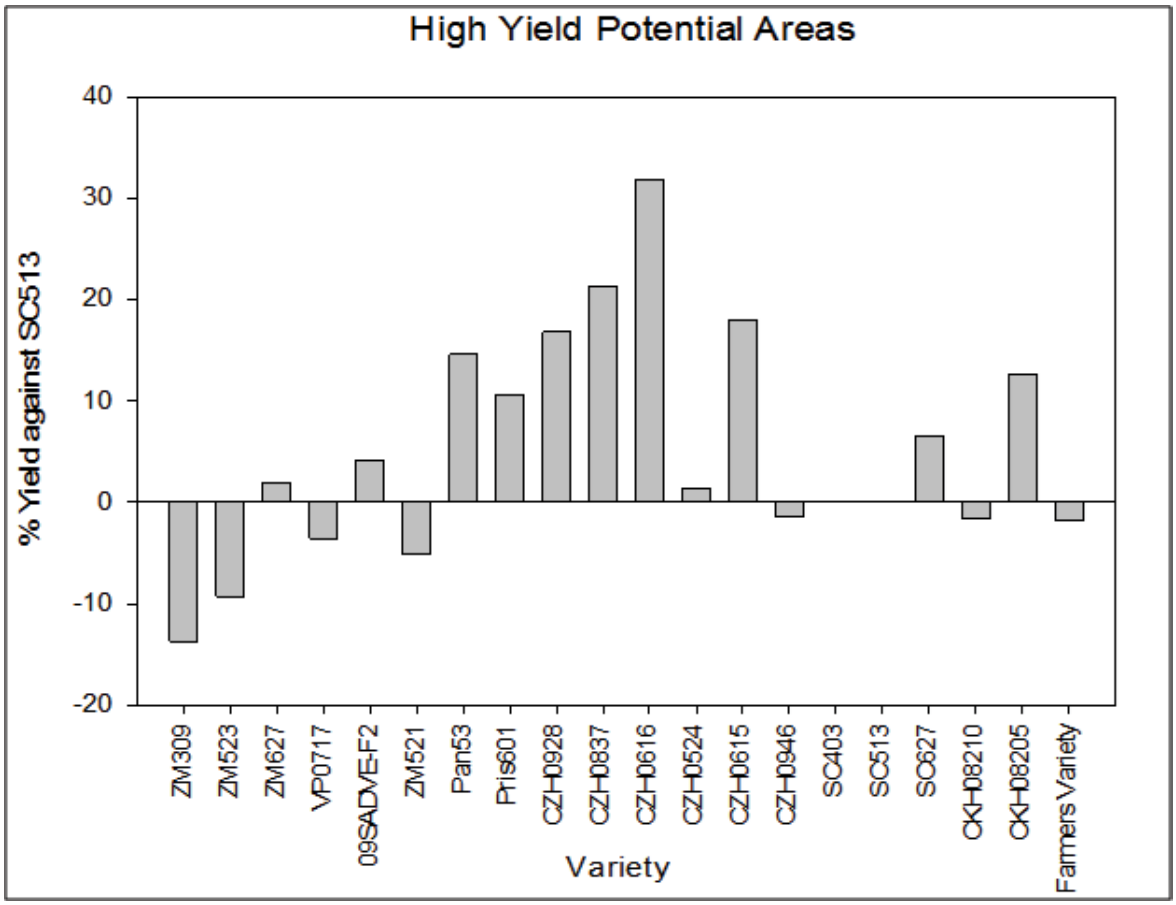

Figure 3. Per cent yield level against SC513 across eastern and southern Africa for trials yielding below 3 tons per hectare.

The results are consistent with Edmeades et al., (2003) who showed that hybrids developed under managed drought and low nitrogen conditions had the largest yielded differentials between 2t ha^{-1} to 5 t ha^{-1} and - became less significant at higher yield levels over private company hybrid checks.

In terms of maturity CZH0946 one of the early DT hybrids was comparable in terms of performance to SC403 one of the very early hybrids most popular early maturing hybrids in southern Africa (Fig 4). Under high yielding trials, the early maturing varieties were out yielded by the medium to late maturing varieties

Repeatability of entry means was 0.79 and 0.51 for the high and low-yielding trials, respectively indicating that highly repeatable means can be estimated from un-replicated on-farm trials (Table 2).

Table 2. Means of maize varieties grown in eastern and southern Africa in2010/2011 season

		Trials grown in southern Africa			Trials grown in eastern Africa			Average yield across eastern and southern Africa for high and low yielding trials	
Variety	Vigor	Average grain yield for trials yielding higher than 3t/ha	Average grain yield for trials yielding lower than 3t/ha		Average grain yield for trials yielding higher than 3t/ ha	Average grain yield for trials yielding lower than 3t/ha		Average grain yield for trials yielding higher than 3t/ha	Average grain yield for trials yielding lower than 3t/ha
ZM309	OPV	3.4	1.7		4.4	2.0		3.9	1.7
ZM523	OPV	3.7	1.4		4.4	0.9		4.1	1.2
ZM627	OPV	4.1	2.0		5.0	1.8		4.6	2.0
VP0717	OPV	4.0	1.8		4.4	1.4		4.4	1.5
09SADVE-F2	OPV	3.8	1.8		5.7	1.2		4.7	1.6
ZM521	OPV	3.8	1.8		4.7	1.0		4.3	1.5
Pan53	Hybrid	4.6	1.7		5.7	0.8		5.2	1.4
Pris601	Hybrid	4.6	1.7		5.2	1.8		5.0	1.7
CZH0928	Hybrid	4.1	1.7		6.8	2.0		5.3	1.7
CZH0837	Hybrid	5.2	2.3		5.6	1.0		5.5	1.8
CZH0616	Hybrid	5.5	2.4		5.9	2.1		6.0	2.5
CZH0524	Hybrid	4.0	2.1		5.1	2.4		4.6	2.0
CZH0615	Hybrid	4.6	1.7		6.0	1.5		5.3	1.5
CZH0946	Hybrid	3.9	2.2		5.0	1.9		4.5	2.0
SC403	Hybrid	4.2	2.2		4.7	1.3		4.5	1.9
SC513	Hybrid	4.1	1.6		4.9	1.5		4.5	1.4
SC627	Hybrid	4.4	2.2		5.0	0.2		4.8	1.7
CKH08210	Hybrid	4.0	1.7		4.7	2.0		4.4	1.8
CKH08205	Hybrid	4.8	2.0		4.7	0.9		5.1	1.7
Checks	Various	4.1	1.9		4.4	0.6		4.4	1.6
Mean		4.2	1.9		5.1	1.4		4.8	1.7
LSD		0.7	0.5		0.9	1.3		0.8	0.9
H		0.79	0.52		0.69	0.51		0.94	0.61

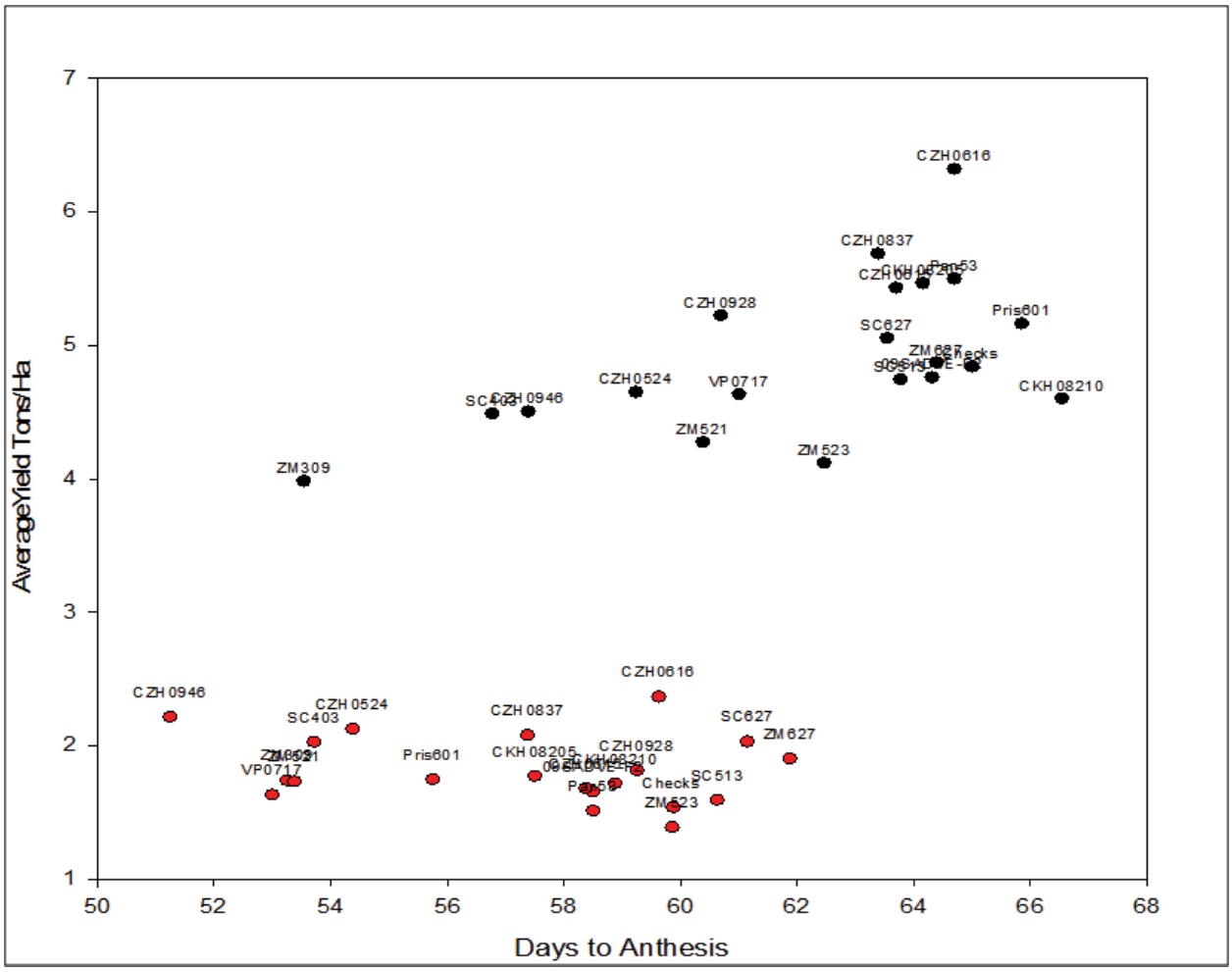

Figure 4. Variety performance in comparison to days to anthesis

Summary

The analysis from the trials shows that under managed drought stress there has been wider genetic progress compared to optimal conditions. Hybrids developed in eastern or southern Africa performed equally in both regions. Hybrids from CIMMYT's stress breeding program showed a consistent advantage over private company hybrid checks at all yield levels.

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