Agronomic potentials of quality protein maize hybrids developed in Ghana

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ABSTRACT

A quality protein maize (QPM) hybrid programme was started in 1991 to develop and promote high and stable-yielding QPM hybrids to increase production of nutritionally superior maize varieties in Ghana. Six 3-way QPM hybrids developed from inbred lines originating from germplasm of the International Centre for Maize and Wheat Improvement (CIMMYT) were evaluated on research stations and in farmers' fields in Ghana from 1995 to 1996. In the on-station evaluations, grain yields across 10 sites in both years averaged 6.0 ton ha^{-1} for the three hybrids (GH132-28, GH110-5 and GH2328-88), 5.22 ton ha^{-1} for Obatanpa, and 3.60 ton ha^{-1} for the local maize variety. In farmers' fields, data from over 50 farm sites in 1995 and 1996 showed mean yields of 4.95 ton ha^{-1} for the three hybrids, and 4.28 ton ha^{-1} for Obatanpa compared to 3.59 ton ha^{-1} for farmers' varieties. On the average, the hybrids were similar to Obatanpa in days to 50 per cent silking, but were shorter in plant height and ear placement. Consumer preference tests showed that the three hybrids were rated similar to the local variety in popular traditional food preparations such as 'kenkey' and 'tuo zafi'. In 1997, the National Variety Release Committee approved the release of GH132-28, GH110-5, and GH2328-88 under the local names Dadaba, Mamaba, and CIDA-ba, respectively. These hybrids are recommended for planting in all the major agro-ecologies to boost maize production in Ghana.

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RÉSUMÉ

SALLAH, P. Y. K., TWUMASI-AFRIYIE, S., AHENKORA, K., ASIEDU, E. A., OBENG-ANTWI, K., OSEI-YEBOAH, S., FRIMPONG-MANSO, P. P., ANKOMAH, A. & DZAH, B. D.: *Potentiels agronomiques de hybrides de maïs protéique de qualité développes au Ghana.* Les variétés de maïs hybride (*Zea mays* L.) dont les plus sésirées que les variétés de pollinisation libre à cause de leur uniformté et leurs potentiels de rendement plus élevés. Pour augmenter la production de variétés de maïs nutritionnellement supérieures au Ghana, I'Institut de Recherche de Cultures a mis en place un programme hybrid de maïs protéique de qualité (MPQ) en 1991 pour développer et promouvoir des hybrides de MPQ de rendement élevés et stable. Six hybrids en trois de MPQ développés d'issu de la même souch provenant de germeplasmes de CIMMYT (Centre International pour I'amélioration de maïs et de blé) étaient évalués aux stations de recherches et aux champs d'agriculteurs au Ghana de 1995 à 1996. Dans les évaluations sur place, les rendements de grain à travers 10 sites dans les deux années ont atteint la moyenne de 6.0 ton ha^{-1} pour les trois hybrids (GH132-28, GH110-5 et GH2328-88), 5.22 ton ha^{-1} pour 'Obatanpa' et 3.60 ton ha^{-1} pour la variétés de maïs local. Sur les champs d'agriculteurs des données de plus que 50 sites de champs en 1995 et 1996 montraient les rendements moyens de 4.95 ton ha^{-1} pour les trois hybrids et 4.28 ton ha^{-1} pour les 'Obatanpa' comparées à 3.59 ton ha^{-1} pour les variétés d'agriculteurs. En moyenne, les hybrides étaient semblables à 'Obatanpa' en jours jusqu à 50% d'apparition de soie maïs étaient plus courtes en taille de plante et en placement d'épi. Les essais de préférence de consommateur montraient que les trios hybrides étaient évalués semblables à la variété locale dans les préparations de nouriture traditionnelle populaire telle que 'kenkey' et 'tuo zafi'. En 1997, le comité pour la mise en vente de Variété Nationale a approuvé la mise en vente de GH132-28, GH110-5 et GH2328-88 sous les noms locaux respectifs de Dadaba, Mamaba, et CIDA-ba. Ce hybrides sont recommandés pour la popultion dans toutes les agroéclogies majeures pour stimuler la production de maïs au Ghana.

Introduction

The development of hybrid maize is an outstanding technological success of the century (Tolessa *et al.,* 1996). Hybrid maize genetics show that vigour is reduced as a result of inbreeding and vigour restored on crossing inbred parents (Sprague & Dudley, 1988). In 1926, Henry Wallace of Pioneer Hybrid International produced and sold the first hybrid maize in the USA. Today, average hybrid maize yields in the USA are over 7.0 t ha^{-1}, with some farmers recording up to 20 t ha^{-1}. Soon, even higher yields will be realized because the maize plant is a very efficient system that can use environmental resource for yield increase (Sprague & Dudley, 1988).

Zimbabwe was the first country in the world to release a single-cross hybrid for commercial production. And starting nearly from zero in 1930, by 1990 all the maize production in the country was reported to have come from hybrid seed (Lopez-Pereira & Fillippello, 1995). The maize breeding programme of Zimbabwe evolved through the stages of open-pollinated varieties, double-cross hybrids, single-cross hybrids, top-cross hybrids, and modified single-cross hybrids (Machida, 1996). Kenya and Ethiopia are other African countries in which improved hybrids developed by national maize-breeding programmes have been adopted by most large-scale commercial and small subsistence farmers.

Recognizing the high and stable yields associated with hybrid maize development, the Crops Research Institute (CRI) started hybrid maize development in 1986. Maize variety development in Ghana in the past concentrated on developing open-pollinated maize varieties because of socio-economic reasons (Twumasi-Afriyie *et al.,* 1997). These included constraints such as lack of efficient seed production and distribution system, poor road infrastructure, and expected higher cost of hybrid seed. Early efforts were aimed at developing three-way normal maize hybrids and testing single and three-way hybrids developed by the International Centre for Maize and Wheat Improvement (CIMMYT), Mexico (Twumasi-Afriyie *et al*., 1997). Although some promising normal maize hybrids were identified (Badu-Apraku, Sallah & Twumasi-Afriyie, 1991), further efforts to test them on farmers' fields produced inconclusive results. Single crosses from the international centres could not be recommended by performance over the existing composite varieties in Ghana.

A quality protein maize (QPM) development programme in Ghana started in 1989 at the main stations of the CRI at Kwadaso and Fumesua in the forest region of Ghana, with collaboration from the Nyankpala Agricultural Experiment Station (NAES) (Twumasi-Afriyie *et al*., 1994a, 1994b, 1994c). This programme led to the release of an open-pollinated variety, Obatanpa, which has been widely adopted in Ghana (Twumasi-Afriyie *et al*., 1992, 1994b). The release of Obatanpa generated wide interest in QPM, leading to requests for the variety from several countries in Africa and elsewhere. While developing Obatanpa, a QPM hybrid programme was concurrently started in 1991 to develop high-yielding, widely adapted, fertilizer-responsive hybrid varieties that are resistant to important diseases and insect pests.

This study aimed to determine the yield potentials of elite QPM three-way hybrids in the major agro-ecological zones of Ghana, and to identify the best hybrid variety for release to farmers.

Materials and methods

Several inbred lines were developed from QPM Populations 63 (tropical, intermediate white dent QPM) and 62 (tropical, intermediate white flint) collected from CIMMYT. Some inbred lines were screened under artificial streak pressure to identify those with resistance to the maize streak virus disease (Twumasi-Afriyie *et al*., 1994b). A QPM population, GH8363 SR, was used to topcross to several of the inbred lines to determine their combining ability (Twumasi-Afriyie *et al.,* 1994b). After the topcross evaluation in 1991, inbreeding was pursued

continuously to obtain genetic and morphological homogeneity. The inbred lines were then combined in all possibilities in pairs to identify inbred lines with the best specific and general combining abilities. These were evaluated widely at experiment stations of CRI and SARI in the major agro-ecological zones of Ghana. Variety evaluations were organised into preliminary hybrid, advanced hybrid, station variety, on-farm variety, and international trials. Hybrid varieties were progressively eliminated based on performance, and only the most promising ones were advanced into the next testing stage.

The evaluations led to the selection of six hybrids, technically named GH110-5, GH110-88, GH132-28, GH110-28, GH2328-88 and GH2823-140T. These were simultaneously tested in farmers' fields in Ghana and in an international QPM trial offered by the CRI Maize Programme in 1995 and 1996 (Twumasi-Afriyie *et al*., 1997). The on-farm test sites were in the Forest, Transition, Coastal Savanna and Guinea Savanna. The international test locations were in Benin, Nigeria, Ivory Coast and Guinea in West Africa; Zimbabwe and South Africa in southern Africa; Tanzania in East Africa; Congo in Central Africa; Guatemala and Mexico in Central America; and Brazil in South America. There were 10 entries in the trial, which consisted of eight medium-maturing varieties developed in Ghana comprising six QPM three-way hybrids, Obatanpa (QPM open-pollinated) and Abeleehi (normal non-QPM maize open-pollinated), plus two checks nominated by cooperating scientists. The cooperators were asked to use two leading varieties under production in their area as the local checks.

In the international testing, a randomized complete block design with four replications was used. Randomization was completed at CRI and seed packets were marked with appropriate plot numbers. Seed packets were filled and serially arranged in the order they were to be planted in the field. Four empty envelopes for each of the two local check varieties were included in the package for the trial. Seeds were treated with Marshal 25 ST (a red, powdery systemic insecticide with carbofuran as an active ingredient), and the same quantity of the insecticide was placed in each empty seed envelope for the check varieties.

Each plot consisted of four rows, with each row being 5.0 m long. The between-row spacing was 75 cm. Two plants per hill were maintained at a spacing of 45 cm between hills, resulting in plant density of 53,333 plants ha^{-1} (GGDP, 1996). Data were collected from the two central rows of each plot, following standard procedures. The data collected included plant stand, number of days that 50 per cent of plants in a plot extruded silk, plant height, ear height, root and stalk lodging, score of husk tip-cover tightness, grain moisture at harvest, ear-aspect and field weight of grain at harvest. Major diseases were scored at each location, following standardized procedures. Details of experimental procedures were collected from cooperators and any differences reported were considered in the analyses.

Seven maize varieties–GH110-5, GH132-28, GH2328-88 (QPM hybrids); Obatanpa (QPM open-pollinated); NAES EE W-SR, Dorke SR (both improved normal maize); and Local variety (normal maize)–were processed into 'tuo zafi' (TZ), Ga and Fanti 'kenkey'. The foods were prepared by the staff of WIAD-MOFA and local food producers. For each food, 20 sensory evaluation panelists, who were producers or consumers or both, evaluated the varieties. The panelists rated the samples for overall acceptability (taste, texture, appearance) by how much they liked or disliked each sample. The rating was converted to scores on a seven-point hedonic scale: like very much = 7, like moderately = 6, like slightly = 5, neither like nor dislike = 4, dislike slightly = 3, dislike moderately = 2, dislike very much = 1. Data were analyzed using ANOVA, and Duncan's Multiple Range Test (DMRT) was applied to determine significance between sample means.

Results

Table 1 shows the names and some characteristics

of maize varieties tested in local and international trials during the period 1994-1996. The results of on-station evaluation at six locations in 1994 showed that the three hybrids GH132-28, GH110-5 and GH2328-88 produced grain yields of 5600, 5500 and 4900 kg ha^{-1}, respectively, compared with 4300 kg ha^{-1} for Obatanpa and 3000 kg ha^{-1} for the local variety (Table 2). The three hybrids were 19-28 and 29-38 per cent more productive than Obatanpa and Abeleehi, respectively. In 1995, the mean grain yield over 10 locations (Fumesua and Kwadaso in the Forest zone; Pokoase and Ohawu in the Coastal Savanna zone; Ejura and Kpeve in the Transition zone; Nyankpala, Damongo and Yendi in the Guinea Savanna zone; and Manga in the Savanna zone) of the three hybrids GH110-5, GH132-28 and GH2328-88 were 7300, 6800 and 6300 kg ha^{-1}, respectively (Table 3). In 1996, the three hybrids produced grain yields of 5200 to 5300 kg ha^{-1} compared with 4600 kg ha^{-1} for Obatanpa and 3100 kg ha^{-1} for the local. The hybrids yielded 15-18 per cent higher than Obatanpa. Generally, differences in grain yield among the hybrids were not significant.

Two of the hybrids, GH132-28 and GH110-5, were tested in the 120-day On-Station Variety Trial that also included several normal (non-QPM) maize hybrids in 1995 and 1996. In both years, the QPM hybrids were the most productive in the trials and out-yielded the normal (non-QPM) hybrids and Okomasa, improved normal maize (Table 4). The advantage in grain yield over Okomasa was 12-23 per cent in 1995 and 8-15 per cent in 1996.

Combined analysis of trials in over 50 farms in

TABLE 1

Names and Some Characteristics of Varieties Tested On-station, On-farm, and in International Trials Conducted During the Period 1994-1996

Variety #	*Varietal type*	*Parental source*	*Grain type**
GH2328-140T	QPM 3-way Hybrid	CIMMYT Pop. 62, 63	WF
GH110-28	QPM 3-way Hybrid	Pop. 62, 63	WFD
GH110-5	QPM 3-way Hybrid	Pop. 62, 63	WF
Obatanpa	QPM OPV	GH8363 SR	WD
GH110-88	QPM 3-way Hybrid	CIMMYT Pop. 62, 63	WFD
GH2328-88	QPM 3-way Hybrid	CIMMYT Pop. 62, 63	WFD
GH132-28	QPM 3-way Hybrid	Population 62	WFD
Abeleehi	Normal Maize OPV	CIMMYT Pop. 49	WD
Local Check-1	Normal Maize OPV	Landrace	WFD
Local Check-2	Normal Maize OPV	Landrace	WFD

* W = White F = Flint D = Dent OPV = Open pollinated variety
\# All named varieties possessed resistance to the maize streak virus disease

TABLE 2

Grain Yield of Medium-maturing Maize Varieties Evaluated at Six Locations During 1994 Major Season*

Variety	*Yield (kg ha^{-1})*	*Yield (% Obatanpa)*
GH110-5	5557	128
GH132-28	5468	126
GH2328-88	4852	119
EV 8163 SR	4609	106
Obatanpa	4335	100
Aburotia	4325	100
Aburotia SR	4307	99
Abeleehi	3902	90
Local	3006	69
Mean	4603	
LSD (0.05)	487	
CV (%)	19	

* Kwadaso, Pokoase, Kpeve, Ejura, Nyankpala, and Kwadaso

collaboration with field staff of CRI, SARI and MOFA as well as cooperating farmers in 1995 and 1996 showed that the three hybrids were again more productive than Obatanpa and farmers' varieties. The three hybrids were 12-20 per cent higher yielding than Obatanpa (Table 5). The difference in grain yield was even greater when the hybrids were compared with the farmers' variety in both years. Plant and ear heights of GH110-5 were the shortest among the hybrids (Table 6). Both GH132-28 and GH2328-88 had similar plant height as Obatanpa. For maturity ratings, the hybrids flowered in 57, 53 and 53 days, respectively, compared with 55 by Obatanpa; indicating that they had intermediate maturity periods.

Mean grain yield over eight locations in four West African countries ranged from 3200 to 4900 kg ha^{-1} (Table 7). Four QPM hybrids GH110-5, GH110-88, GH132-28 and GH2328-88 out-yielded the two local checks included by the collaborators by 20-27 per cent. These hybrids also out-yielded the normal maize check variety, Abeleehi, by 29-36 per cent and the QPM composite variety, Obatanpa, by 12-18 per cent. Mean grain yield over seven locations in four southern African countries ranged from 5000 to 6900 kg ha^{-1}. The GH132-28 variety was the most outstanding QPM hybrid in this zone. It produced a mean grain yield of 6500 kg

TABLE 3

Grain Yield of Medium-maturing Maize Varieties Tested at 10 Locations During 1995 and 1996 Major Season*

Variety	*Yield (kg ha^{-1})*		*Yield (% Obatanpa)*	
	1995	*1996*	*1995*	*1996*
GH110-5	7349	5175	124	115
GH132-28	6790	5316	115	118
GH110-28	6644	5311	112	118
GH2328-88	6305	5057	107	112
GH110-88	6146	4744	104	105
Obatanpa	5917	4513	100	100
GH2823-140T	5784	4601	98	102
Abeleehi	5701	3601	96	80
EV EJ 105	5350	3863	90	86
Local	4071	3119	69	69
Mean	6006	4530		
LSD (0.05)	316	250		
CV (%)	16.9	16.1		

Fumesua, Kwadaso, Pokoase, Ohawu, Ejura, Kpeve, Nyankpala, Damongo, Yendi, and Manga

TABLE 4

*Grain Yield (kg ha^{-1}) of Full Season Maize Varieties Tested During Major Season in 1995 and 1996 at Eight Locations**

Variety	*Yield (kg ha^{-1})*		*Yield (% Okomasa)*	
	1995	*1996*	*1995*	*1996*
GH132-28	6825	5624	123	115
GH110-5	6725	5281	121	108
(GH3X1368) X 9701	6243	5150	112	106
ENT132H-88	6121	5235	110	107
120 DWDMP	6025	4678	108	96
(GH3X1368) X 5012	5962	5150	107	106
(GH20X1368) X 5012	5952	5108	107	104
(GH22X1368) X 5012	5735	4980	103	102
Okomasa	5554	4880	100	100
Dobidi	4905	4855	88	99
8321-18	4432	4762	80	98
Local	4226	3451	76	71
Mean	5752	4900		
LSD (0.05)	151	278		
CV (%)	16.4	16.4		

* Fumesua, Kwadaso, Pokoase, Ohawu, Ejura, Kpeve, Nyankpala, and Damongo

TABLE 5

Mean Grain Yield of QPM Hybrids Tested 0n-farm in Four Agro-ecological Zones in Ghana in 1997

Variety	*Yield (kg ha^{-1})*					*Yield (%) Obatanpa*
	Forest zone	*Transition*	*Coastal Savanna*	*Guinea Savanna*	*Across*	
GH110-5	4700	5661	3668	6534	5147	120
GH2328-88	4898	5252	3357	5786	4941	115
GH132-28	5013	5023	2528	5473	4773	112
GH110-28	4028	5244	4282	5529	4687	110
Obatanpa	4103	4785	2724	5505	4280	100
GH2328-140T	3929	4306	2424	4289	3937	100
Local	3220	4510	2236	4429	3589	92
Mean	4270	4969	3031	5364	4479	
LSD (0.05)	232	253	285	199	207	
CV (%)	16.8	17.1	19.6	18.3	16.4	

TABLE 6

Maturity Ratings, Height, Lodging and Streak Infection of Medium-maturing Varieties Tested at 10 Locations in 1996 Major Season

Variety	*Mid-silk (days)*	*Plant height (cm)*	*Ear height (cm)*	*Grain moisture (%)*	*Total lodging (%)*
GH132-28	57	187	83	21.1	28
GH110-28	55	176	80	20.5	25
GH110-5	53	171	77	20.5	33
GH2823-88	53	185	75	19.0	22
GH110-88	52	177	76	19.0	24
GH2823-140T	57	185	85	21.6	21
Obatanpa	55	198	91	19.8	29
EV EJ 91 105-DWD	52	169	80	19.4	24
Abeleehi	55	157	71	19.8	22
Local	58	201	209	19.4	33
Mean	55	179	83	20.0	26
LSD (0.05)	2.7	7.4	12.7	6.9	36.0
CV (%)	0.5	4	4	0.4	2

ha^{-1} that was not significantly different from those of the local checks. Note that GH132-28 and GH110-5 in particular were as productive as the local checks. Three QPM hybrids GH132-38, GH110-5 and GH2328-88 produced significantly higher grain yield of 10 to 26 per cent than Obatanpa in the region. The GH132-28 variety also out-yielded the normal maize check variety, Abeleehi, by 29 per cent. Mean grain yield over seven locations in three southern American countries ranged from 4000 to 6900 kg ha^{-1}.

Table 8 shows the overall acceptability scores for maize varieties in 'kenkey' and 'tuo zafi'. The results showed that for 'fante kenkey', the local

variety was significantly preferred to GH110-5, but was not different from GH2328-88 and GH132-28. In 'ga kenkey', no differences were observed in the scores for the hybrids and the local maize variety. However, in 'tuo zafi', the hybrids were preferred to the local maize.

TABLE 7

Grain Yield of QPM Hybrids Tested in West and Southern Africa and South America in 1995 and 1996

Variety	*Yield (kg ha^{-1})*		
	West Africa[1]	*South Africa*[2]	*South America*[3]
GH110-5	4804	5748	4958
GH110-88	4658	5213	5008
GH132-28	4617	6488	5379
GH110-28	4545	5957	5139
GH2328-88	4181	5655	6167
Obatanpa	4067	5140	4005
GH2823-140T	4050	5205	5291
Local Check-2	3812	6924	6896
Local Check-1	3751	6419	6624
Abeleehi	3535	5347	5295
Mean	4202	5710	5376
No. of sites	8	7	6
CV (%)	16.0	14	16.4
LSD (0.05)	341	507	503

[1] Benin, Nigeria, Ivory Coast, and Guinea
[2] Zimbabwe, Tanzania, Congo, and South Africa
[3] Brazil, Guatemala, and Mexico

TABLE 8

Overall Acceptability Scores of Maize Varieties in 'Kenkey' and 'Tuo Zafi' Traditional Cereal Foods

Maize variety	*Overall acceptability**		
	Fante kenkey	*Ga kenkey*	*Tuo zafi*
GH 110-5	6.20ab	5.60a	5.87ab
GH 132-28	4.87c	5.47a	6.21a
GH2328-88	5.13c	5.48a	6.14a
Obatanpa	6.47a	5.60a	5.50c
NAES EE	5.13c	5.67a	5.36bc
Local	5.53bc	6.07a	4.93c
Dorke SR	6.39a	5.87a	-

* Overall attributes included taste, texture, and appearance
a-c Means on same column with different letters are significantly different (P<0.05)

Discussion

The three hybrids GH132-38, GH110-5 and GH2328-88 are medium-maturing varieties like Obatanpa, the open-pollinated QPM variety. The on-station and on-farm data showed that the hybrids yielded higher than the open-pollinated varieties, irrespective of the maturity period of the later varieties. About 10 per cent yield decrease resulted with the on-farm experiments, indicating that the extent of applying technological package associated with hybrid development is crucial to realizing the full potential of the hybrids. Ghana's QPM varieties have a wide range of adaptation because they performed creditably well in international trials. However, the hybrids differed in their performance in different environments. Nevertheless, they yielded more than open-pollinated varieties and local checks. The hybrids were highly acceptable for preparing traditional foods, although the quality differed with different food preparations.

Ethiopia's maize hybrids yielded between 13-26 per cent (on-station) and 30-55 per cent (on-farm) more than improved released maize varieties (Tolessa *et al*., 1996). Rattray (1988) reported yield increases of 18 to 60 per cent due to the shift from open-pollinated to hybrid maize varieties. Tattersfield (1982), using data from the commercial farming sector, estimated that between 1946 and 1980 research in Zimbabwe led to increase of up to 325 per cent in maize yield, with hybrid variety technology contributing 45 per cent of the yield improvement. In Ethiopia, the high yield recorded by growing hybrids encouraged farmers to continue growing them, and the demand for hybrid seed and the area under hybrid maize increased substantially. This increase

in the area for producing hybrid maize was one of the major factors for the bumper harvest of maize in Ethiopia in the 1995-1996 crop season (Tolessa *et al*., 1996). Although, it is difficult to separate yield improvement due to hybrid technology from that recorded by other disciplines such as extension services, agronomy, plant protection, soil productivity and seed industry, maize hybrid research led to Zimbabwe's revolution in maize yields (Machida, 1996). The technological success with hybrid development in other countries could be repeated in Ghana.

Conclusion

The QPM hybrids GH132-28, GH110-5 and GH2328-88 developed by Ghana's maize-breeding programming yielded more than open-pollinated varieties and were acceptable in traditional Ghanaian foods. The technological success with QPM hybrid development is expected to lead to a revolution in Ghana's maize production.

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