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% 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 CIDAb-a, respectively. These hybrids are recommended for planting in all the major agro-ecologies to boost maize production in Ghana.

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 développés au Ghana. Les variétés de maïs hybride (Zea mays L.) dont les plus désirées que les variétés de pollinisation libre à cause de leur uniformité et leurs potentiels de rendement plus élevés. Pour augmenter la production de variétés de maïs nutritionnellement supérieures au Ghana, l’Institut de Recherche de Cultures a mis en place un programme hybride de maïs protéique de qualité (MPQ) en 1991 pour développer et promouvoir des hybrides de MPQ de rendement élevés et stable. Six hybrides en trois de MPQ développés d’issu de la même souch provenant de germplasmes de CIMMYT (Centre International pour l’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 hybrides (GH132-28, GH110-5 et GH2328-88), 5.22 ton ha\(^{-1}\) pour ‘Obatanpa’ et 3.60 ton ha\(^{-1}\) pour les 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 hybrides 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 mais étaient plus courtes en taille de plante et en placement d’épi. Les essais de préférence de consommateur montraient que les trois hybrides étaient évalués semblables à la variété locale dans les préparations de nourriture 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 CIDAb-a. Ce hybrides sont recommandés pour la population dans toutes les agroécologies 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, topcross 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). 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 Kpado 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

| 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                |
| Abutoria | 4325                   | 100                |
| Abutoria SR | 4307                   | 99                 |
| Abeleehi | 3902                   | 90                 |
| Local | 3006                   | 69                 |

Mean 4603

LSD (0.05) 487

CV (%) 19

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

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 DWDM      | 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, Damongo, Yendi, and Manga
Table 5

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

| Variety         | Yield (kg ha\(^{-1}\)) | Yield (%) | Obatanpa |
|-----------------|-------------------------|-----------|-----------|
|                 | Forest zone | Transition | Coastal | Guinea | Savanna | Across | Obatanpa |
| 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
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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.

**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.

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

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**Table 7**

| Variety     | Yield (kg ha⁻¹) |
|-------------|----------------|
|             | West Africa¹ | South Africa² | South America³ |
| 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          |
| Abelelehí   | 3535         | 5347         | 5295          |

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**Table 8**

| 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     | -        |

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* Overall attributes included taste, texture, and appearance.

a-c Means on same column with different letters are significantly different (P<0.05)
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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