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Marginal Rate Of Returns of Local and Improved Open Pollinated Maize Varieties Compared With Quality Protein Maize Hybrids in Ghana

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ABSTRACT

Maize variety development in Ghana in the past mainly concentrated on developing open-pollinated varieties (OPVs). Since malnutrition especially protein deficiency is a major problem amongst most children in Ghana and for higher grain yields it was prudent that Quality Protein Maize (QPM) hybrids be developed. The Crops Research Institute released Obatanpa an OPV QPM, Mamaba and Dadaba (QPM hybrids) amongst others. Thus, it became necessary to study the economic benefits of moving from the local to improved OPVs and subsequently QPM hybrids. Field evaluations were done in the 2002 major and minor seasons at Fumesua and Kwadaso in forest zone. Three local varieties and seven improved OPVs and two QPM hybrids were evaluated. A marginal rate of return (MRR) of 2176% and 194% was observed by replacing local varieties with the QPM hybrids at zero N and 45 kg N to the QPM hybrids respectively.

Key words: *Malnutrition, Obatanpa, Mamaba, Dadaba, Economic Benefits*

1. INTRODUCTION

Quality Protein Maize (QPM) produces 70–100% more of lysine and tryptophan than most modern varieties of tropical maize. Infants, livestock and poultry fed on QPM grew faster and healthier when compared to the normal maize varieties. Protein deficiency among children is common especially in northern Ghana where meat, fish and eggs are beyond the means of the average family with low incomes. Thus, the adoption and utilization of QPM may be a way of alleviating malnutrition, particularly in children (Buah et al. 2010). Maize variety development in Ghana in the past was concentrated on developing open-pollinated maize varieties because of socio-economic reasons, which included lack of efficient seed production and marketing systems. It was later realized that hybrid maize was more productive than the open-pollinated varieties (OPVs). Therefore, most leading maize production countries in the world depended largely on hybrid maize. A QPM development programme in maize was started in 1989 at the Crops Research Institute. This initially led to the release of an open-pollinated variety, Obatanpa, which has been widely adopted in Ghana and elsewhere in Africa and beyond. Alongside the development of Obatanpa, a QPM hybrid maize development programme was initiated in 1991. Three 3-way QPM hybrids, namely, GH110-5 (Mamaba), GH132-28 (Dadaba) and GH2328-88 (CIDA-ba) were developed in this programme and were very productive, yielding between 6.3 and 7.3 t ha^{-1} on experimental station, which represented an increase of 19 to 38 per cent over Obatanpa (Asiedu et al. 2004). Newer hybrids may be superior to the older cultivars in both high and low fertility areas with greater superiority in the higher fertility area (Castleberry et al. 1984). Most modern improved cultivars have better nitrogen use efficiencies and are therefore more desirable in grain production (Moll et al. 1982). Improved cultivars are likely to respond to fertilizers than the local or old varieties. (Sallah 1997) observed that the greatest yield response to N was at 80 kg ha^{-1} for all cultivars and showed that improved cultivars out-yielded the local cultivar at low as well as at higher levels of soil fertility. Breeding could be effective in improving yield potential of maize under low as welI as high levels of soil fertility (Sallah et al. 1998). Improved maize cultivars could be more efficient in using fertilizer N than the local varieties (Sallah and Twumasi-Afriyie 1999). Crop growth and development depends on available nutrients for plant uptake. The major nutrients notably Nitrogen, Phosphorous and Potassium are taken up gradually during seedling growth and rapidly during active vegetative growth and grain filling stages (Hanway 1966). Adequate supply of plant nutrients are needed for protein, amino acid, energy synthesis and improved metabolic activities (Veldkamp 1992). In order for farmers to realize economic benefits from their farms, various interventions are made. These may include the use of improved seeds, fertilizers (organic and inorganic), planting in rows, seed treatment, improved tillage practices, research and extension just to mention a few. Several studies are reported of such interventions. Arega et al. 2009 assembled the results of three multi country surveys on variety performance and adoption patterns to measure the impacts of maize research in West and Central Africa from 1981 to 2005, and used cost data since 1971 to compute social rates of return on public investments in maize research in the region. Adoption of modern varieties increased from less than 5% of the maize area in the 1970s to about 60% in 2005, yielding an aggregate rate of return on research and development (R&D) investment of 43%. The estimated number of people moved out of poverty through adoption of new maize varieties rose gradually in the 1980s to more than one million people per year since the mid 1990s. Over half of these impacts were attributed to international maize research at International Institute of Tropical Agriculture in Ibadan-Nigeria and the International Centre for Maize and Wheat Improvement in Mexico. Ehsanullah et al. 2015 obtained a maximum marginal rate of return of 2232.79% when maize was sown on ridges under conventional tillage. It was clear from the results that farmers with poor resources could accomplish maximum benefits by sowing the maize hybrid on ridges under conventional tillage system. Selassie (2015) also showed that the MRR with N fertilizer at the rate of 60 kg N ha^{-1} gave the highest MRR of 256.7 % followed by the treatment with N fertilizer rate of 90 kg N ha^{-1}. The treatment with N fertilizer rate of 30 kg ha^{-1} gave MRR below 100 %, which indicated that the rate was not economically optimum. ASHIQ et al. 2006 noted that NP level of 140:70 kg ha^{-1}, as its marginal rate of return was more than the minimum rate of return recommended for the farmers, who could afford more cost of production due to high dose of fertilizer. For the farmers, who couldn't afford much cost and on the basis of maximum marginal rate of return the NP level of 120:60 kg ha-^{1} was recommended for growing maize crop successfully and economically. Makinde et al. 2007 revealed that farmers could gain better if they changed from no fertilizer control to either organic fertilizer (278%) or inorganic fertilizer with a MRR of 1255% respectively. Similar result was obtained in 1996 with organic fertilizer (494%) and inorganic fertilizer (1115%). However, considering the problem of scarcity often associated with inorganic fertilizer, the choice of organic fertilizer was more likely to be accepted by the farmers. Agricultural research and extension programs have been built in most of the worlds' economies. A substantial number of economic impact studies evaluating the contributions of research and extension program to increased farm productivity and farm incomes and to consumer welfare have been undertaken in recent years. In several categories of studies, median (social) estimated rates of return were high, (often exceeding 40 percent) and one could state that most of the estimates were consistent with actual economic growth experiences (Evenson 2001). In Kenya, absolute income gains to fertilizer are reasonably substantial. However, the average acreage under maize cultivation for all farmers in this area is 0.93 acres. Without fertilizer or hybrid seed, this would produce about 8,000 Ksh ($242) worth of maize on average. Using ½ tea-spoon of top dressing fertilizer per hole would increase agricultural income (net of fertilizer cost) by about 1,100 Ksh ($33). This represented a 15 percent increase in net income and more than a month's agricultural wages. The fixed cost of using fertilizer alone is therefore unlikely to be the whole story, as long as farmers are able to use fertilizer on their entire plot. It may, however, still play an important role in cases in which the farmer's optimal use would be less than the full plot (Duflo et al. 2008). In some recent work, these scientists investigated two reasons for low adoption of fertilizer: lack of information and savings difficulties. Their findings suggested that simple interventions that affected neither the cost of, nor the payoff to, fertilizer can substantially increase fertilizer use. In particular, offering farmers the option to buy fertilizer (at the full market price, but with free delivery) immediately after the harvest led to an increase of at least 33 percent in the proportion of farmers using fertilizer, an effect comparable to that of a 50 percent reduction in the price of fertilizer. This finding seemed inconsistent with the idea that low adoption was due to low returns or credit constraints, and suggested there may be a role for non-fully rational behavior in explaining production decisions. Their findings also contributed to the growing body of evidence suggesting that returns to capital in developing countries were often high. (Buah et al. 2010) conducted trials in the Guinea savanna ecology of Ghana to evaluate yield response of quality protein maize (*Zea mays* L.) hybrid to plant density and nitrogen (N) fertilizer. The experiments were conducted at four locations on 16 farmers' fields in 2002 and 2003. Three N rates (0, 90 and 135 kg ha^{-1}) were combined with three plant densities (50 000, 62 500 and 71 400 plants ha^{-1}) to constitute nine treatments which were tested in a randomized complete block design. Optimal N rate was not affected by plant density. There was no yield response to plant density. However, grain yield had a linear and quadratic response to N at all sites. Grain yield increased as a result of 90 kg N ha^{-1} applied over the farmers' practice (0 kg N $ha^{-1'}$) at Tumu, Jirapa, Kpongu and Wa were 39%, 85%, 101% and 303% in 2002, respectively. Grain yield increases for the same rate and sites in 2003 were 31%, 83%, 63% and 51%, respectively. Marginal rate of return (MMR) to 90 kg N ha^{-1} combined with 62 600 plants/ha was the highest (5564%). Increasing N rate beyond 90 kg ha^{-1} did not result in corresponding increase in yield nor net benefit to merit the extra cost that may be incurred. From the study, application of 90 kg N $ha^{-'}$ to hybrid maize would give economic yield response and acceptable returns at low risk to farmers, regardless of plant density. Storage systems are also part of the interventions to increase farmers' income. (Adetunji 2007) investigated 3 maize storage techniques being used by respondents namely Local Storage (LS), Semi-Modern storage (SMS) and Modern Storage (MS). The gross margin for using various storage techniques were N8345 t^{-1} (LS), N11,135 t^{-1} (SMS) and N12,435 t^{-1} (MS). MS was the best technique because it had the highest MRR. With the release of QPM hybrids in Ghana and their promotion it became necessary to study the economic benefits of moving from the local to improved OPVs and subsequently QPM hybrids.

2. MATERIALS AND METHODS

The study was conducted during the 2002 major and minor seasons at Fumesua and Kwadaso in the forest zone which lie on latitude 6^0 43' N and longitude 1^0 36' W. The experimental design was a two factor randomized complete block design in split plot arrangement with four replications in each environment. The nitrogen levels and varieties were randomized in the main plots and sub- plots respectively. Fields were slashed and harrowed. Each variety was planted in two row plot, 5 m long with spacing of 75 cm between rows and 22.5 cm within rows given a plant population of 59,260. Three seeds were planted per hill and later thinned to one plant per hill. All the genotypes received a basal application of phosphorus (P) as triple super phosphate at 60 kg P_20_5 ha^{-1} and potassium (K) as potassium chloride (KCl) at 30 kg K_20 ha^{-1}. Nitrogen was applied as sulphate of ammonia at 0, 45, and 90 kg N ha^{-1}. Data were recorded from the two-row plot of each variety. Grain yield was expressed in kg/ha at 15 % moisture using the formula: Grain yield = (Grain weight (kg)/harvested area × (10,000m^2 /ha) × (100 – % grain moisture)/85. The data were analyzed for each environment and combined over environments according to using the MSTAT-C soft ware (Michigan State University, East Lansing, M1). Economic analysis to determine the marginal rate of returns for the grain weight component was done based on method used by CIMMYT 1988.

3. RESULTS AND DISCUSSIONS

Grain yield response of the 12 genotypes to N application is presented in Table 1

Genotypes responded positively to increase in N levels. Yields generally increased in the order 90 kg N ha^{-1} >45 kg N ha^{-1} > 0 kg N ha^{-1}. Grain yield under zero N ranged from 2.5-3.4 tons ha^{-1}. The highest yield of 3.4 tons ha^{-1} under zero N was obtained in Obatanpa though this yield was not significantly different from Dadaba. The lowest yield was obtained in Ohawu local. Grain yield at 45 kg N ranged from 2.9-5.4 tons ha^{-1}. The highest yield of 5.4 tons ha^{-1} was obtained in Mamaba and the lowest yield again was obtained in Ohawu local. Grain yield at 90 kg N ranged from 3.4-6.0 tons ha^{-1}. The highest yield of 6.0 tons ha^{-1} was obtained in Mamaba and the lowest yield again was
obtained in Ohawu local. High yields obtained confirmed that obtained by most scientists that improved varieties especially hybrids were responsive to fertilizers (Castleberry et al. 1984, Moll et al. 1982, Sallah et al. 1997, Sallah et al. 1998; Sallah and Twumasi-Afriyie, 1999).

Table 1. Mean grain yields (kg ha^{-1}) of 12 maize genotypes evaluated under 3 levels of nitrogen in 4 environments of year 2002

		.........Grain Yield kg/ha…………			
Variety	Type of variety	0N	45N	90N	Mean
Ohawu local	Local OPVN †	2473	2900	3445	2939
AA92/014[B]	Local OPVN	2881	3596	4220	3566
AA92/015[B]	Local OPVN	2588	3229	3901	3239
Golden crystal	Improved OPVN	2815	3731	4544	3697
Composite 4	Improved OPVN	2877	3283	3683	3281
Aburotia	Improved OPVN	2930	3951	3954	3612
Dobidi	Improved OPVN	3051	3842	4478	3790
Okomasa	Improved OPVN	3011	3675	4552	3746
Abeleehi	Improved OPVN	3001	3690	4279	3657
Obatanpa	Improved OPVQPM§	3399	4145	4841	4128
Mamaba	Improved 3WHQPM‡	2898	5405	5533	4612
Dadaba	Improved 3WHQPM	3307	5170	5951	4809
Mean		2936	3885	4448	3756
LSD (0.05)†					375**
LSD (0.05)‡					216**
LSD (0.05)§					172**
CV%					14.4

**Significant at p<0.01 respectively; †For comparison of genotype means; ‡For comparison of N treatment means; §For comparison of genotypes within N level
†Open Pollinated Variety (Normal maize); ‡Three Way Hybrid (Quality Protein Maize);
§Open Pollinated Variety (Quality Protein Maize)

Mean grain yields for the local varieties, OPVs and the QPM hybrids and their economic analysis for variable cost, gross and net benefits are shown in Table 2.

Table 2. Mean grain yield for the local varieties, OPVs and QPM hybrids and their economic analysis for variable cost, gross and net benefits.

	………Local varieties………………			…………….OPVs………………...			………..QPM hybrids…………….		
	……………..kg N ha-1……….			…………kg N ha-1……………..			……………kg N ha-1……………...		
N-levels	0	45	90	0	45	90	0	45	90
Grain Yield kg ha-1	2647.3	3241.7	3855.3	3012.0	3759.6	4333.0	3102.5	5287.5	5742.0
Gross benefits (GB)	2647,300	3241,700	3855,300	3012,000	3759,600	4333,000	3102,500	5287,500	5742000
Variable cost (₵)									
Seed+	80,000	80,000	80,000	100,000	100,000	100,000	100,000	100,000	100,000
Fertilizer^	0	642,857	1285714	0	642,857	1285714	0	642,857	1285714
Fertilizer Application	0	100,000	200,000	0	100,000	200,000	0	100,000	200,000
Total variable cost (TVC) ₵	80,000	822,857	1565,714	100000	842,857	1,585,714	100000	842,857	1585,714
Net benefits ₵ ha-1 GB – TVC	2567,300	2418,843	2289,586	2912,000	2916,743	2,747,286	3,002,500	4,444,643	4,156,286

Maize grain price=₵1000 kg^{-1} ; +Seed rate was calculated for 20 kg ha^{-1} at ₵5000 kg^{-1} for the improved varieties and ₵4000 kg^{-1} for the local varieties; ^cost of sulpphate of ammonia (S/A) per kg plus transport=₵150,000:S/A contains 21% N so ₵50 kg bag S/A will contain 21/100 × 50=10.5 kg N. Thus 10.5 kg N cost ₵150,000 therefore 1 kg N will cost 150/10.5=₵14,285.71

Mean yields at zero N for the local varieties, OPVs and the QPM hybrids were 2.65 tons ha^{-1}, 3.01 tons ha^{-1} and 3.10 tons ha^{-1}, respectively. The yield difference between the local varieties and the QPM hybrids at zero N was significant. The QPM hybrids out-yielded the local varieties by 17.2% and the OPVs by 3%. On the other hand, OPVs had a 13.8% yield advantage over the local varieties. At 45 kg N ha^{-1}, mean yields for the local varieties, OPVs and the QPM hybrids were 3.24 tons ha^{-1}, 3.76 ton ha^{-1} and 5.29 ton ha^{-1} respectively. The OPVs had a 16% yield advantage over the local varieties and the hybrids had 41% yield superiority over the OPVs at this N level. At 90 kg N ha^{-1}, mean yields were 3.86 tons ha^{-1}, 4.33 tons ha^{-1} and 5.74 tons ha^{-1} for the local varieties, OPVs and hybrids, respectively. This implied a 12.4% yield advantage of the OPVs over the local varieties and a 32.5% yield superiority of the QPM hybrids over the OPVs. Increase in grain yield due to increase in N levels may be attributed to adequate supply of plant nutrients needed for protein, amino acid, energy synthesis and improved metabolic activities as suggested by Veldkamp (1992). Good nutrition enabled proper seedling growth and plant establishment, active vegetative growth and adequate grain filling as reported by Hanway (1966). Significant differences observed in the grain yield between the local varieties and improved varieties at the various N levels were expected. The improved varieties are normally more responsive to fertilizer application and have better nitrogen use efficiencies than land races (Castleberry et al. 1984, Moll et al.1982, Sallah et al. 1997, Sallah et al. 1998, Sallah and Twumasi-Afriyie 1999). The results also indicated the lowest net benefit of ₵2.3 million at 90 kg N ha^{-1} in the local varieties, whilst the highest of ₵4.4 million was obtained at 45kg N ha^{-1} in the QPM hybrids. This may be due to high yields obtained from the QPM hybrids. These results were similar to that obtained by Ehsanullah et al. 2015 but they planted their hybrids on ridges under conventional tillage system.

Dominance analysis is presented in Table 3. The results showed that good options for marginal rate of returns were the QPM hybrids at Zero N and 45 kg N ha^{-1}. The analysis showed that marginal rate of returns of 2176% and 194% were obtained by moving from the local varieties to the QPM hybrids at zero N and QPM hybrids at zero N to QPM hybrids at 45 kg N ha^{-1}.

Table 3. Dominance analysis for local, OPVs and QPM hybrid Maize varieties evaluated in 2002 under four environments.

Varieties	Total variable cost ₵	Net variable cost ₵
0 kg N ha^{-1}		
Local vars.	80,000	2,567,300
OPVs	100,000	2,912,000 D
QPM hybrids	100,000	3,002,500*
45 kg N ha^{-1}		
Local vars.	822,857	2,418,843 D
OPVs	842,857	2,916,743 D
QPM hybrids	842,857	4,444,643*
90 kg N ha^{-1}		
Local vars.	1,565,714	2,289,586 D
OPVs	1,585,714	2,747,286 D
QPM hybrids	1,585,714	4,156,586 D

*Good options for marginal rate of returns

Calculation of the Marginal rate of returns (MRR)
Local var. (0 kg N) to QPM hybrids (0 kg N): 3,002,500 – 2,567,300/100,000 – 80,000 × 100=2176% QPM hybrid (0 kg N) to QPM hybrids (45 kg N):4,444,643 – 3,002,500/842,857 – 100000 × 100=194%

The marginal rate of returns (MRR) of 2176% obtained by moving from the local varieties to the QPM hybrids with no fertilizer implies that, for every one cedi spent on this option, you will get back the cedi you invested plus an additional ¢21.76. This amount is very huge and for that matter a very good option for farmers who cannot afford to purchase fertilizer for their maize production. The MRR of 194% obtained in the QPM hybrids at 45 kg N ha^{-1} implied that if you use the QPM hybrids and could afford to buy fertilizer then, for every one cedi you invested you would get back your cedi and obtain an additional ¢1.94. This is very beneficial because you already have a 2176% advantage by moving from the local to the hybrid. It would therefore be more profitable for farmers to use the QPM hybrids at 45 kg N ha^{-1}. The results were similar to that of Buah et al. 2010. However, in their study maximum MRR was obtained at 90 kg N ha^{-1} as compared to 45 kg N ha^{-1} in this study. This may be due to the fact that the environments were different and soils at the North are very low in nitrogen. High MRR obtained in this study is in accordance with Makinde et al. 2007 who revealed that farmers could gain better if they changed from no fertilizer control to either organic fertilizer (278%) or inorganic fertilizer with a MRR of 1255% respectively.

4. CONCLUSIONS

It was concluded from the study that there was a 41% and 33% yield advantage of planting the QPM hybrids over the OPVs at 45 kg N ha^{-1} and 90 kg N ha^{-1}, respectively and a 49 to 63 % yield increase by replacing the local varieties with the QPM hybrids depending on nitrogen fertilizer rate (45 or 90 kg N ha^{-1}). Secondly, economic analysis of the results indicated a marginal rate of return (MRR) of 2176% by replacing the local varieties with the hybrids at zero N. Finally, the best option for better economic returns was the application of 45 kg N to the hybrids and this gave a MRR of 194%. It was recommended that when one could not afford to purchase fertilizer, the best option was to go in for the hybrids rather than to grow the local varieties.

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