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Response of Maize to Organic Foliar Fertilizer and its Economic Implications to Farmers in Ghana

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ABSTRACT

Field trials were conducted on-station at Kwadaso and Ejura in the forest and forest-savannah transition zones of Ghana, respectively in 2009 and 2010. The foliar fertilizer "Natural Asontem" was tested on maize in the major and minor seasons of the bimodal rainfall regime in the two agro-ecologies. The objectives of the trials were to (1) determine the appropriate dosages for application of the Foliar Fertilizer (FF) on maize for optimum growth and yield performance and (2) assess the economic feasibility of the product. Soil analyses was done for all locations which indicated low percentages of Organic Matter (OM), Nitrogen (N), Phosphorus (P), potassium and low pH levels. In the first year different rates and frequency of application of the foliar fertilizer produced significantly ($p<0.05$) lower yields as compared to the recommended inorganic fertilizer rate. In the second year NPK (15-15-15) was applied as starter and followed by two split applications of the different foliar fertilizer rates. The organic foliar fertilizer improved yield slightly only when in combination with inorganic NPK fertilizer. The recommended chemical fertilizer rate for maize of 90:38:38 kg ha^{-1} (NPK) significantly ($p<0.05$) out-yielded even the combination of NPK (38:38:38 kg ha^{-1}) plus a high dose of 1.8 kg ha^{-1} of Natural Asontem (NA) foliar fertilizer. The foliar fertilizer NA contained only 6.4% soluble nitrogen and no indication of the presence of potassium, phosphorus and the micronutrients. This may have contributed to the relatively poor performance of the FF as compared to the inorganic fertilizer treatment. The economic analysis of the treatments also showed that application of Inorganic Fertilizer (IF) alone was more economical than sole foliar fertilizer or in combination with lower dosage of IF. In order to exploit the full potential benefit of foliar sprays there is the need for scientists to know more about how to reduce leaf scorching even at relatively low concentrations of nitrogen and also prevent losses of nitrogen from the foliage.

Key words: Foliar fertilizer, inorganic fertilizer, partial budget, net benefit, marginal rate of return

INTRODUCTION

Application of foliar fertilizer is an effective way of correcting soil nutrient deficiencies when plants are unable to absorb them directly from the soil (Liang and Silberbush, 2002). Foliar applied fertilizers provide a quicker response and are more effective for some nutrients than soil applied fertilizers (Reickenberg and Pritts, 1996; Jamal *et al.*, 2006). The nature of the soil plays a very vital role in the availability of some micronutrients like Mn, Cu, Zn and Fe which are precipitated in insoluble forms in alkaline soils. However, farmers must be sure that their crops will not be damaged by the foliar fertilizers as some plants are intolerant to this treatment (Gooding and Davies, 1992). In young leaves the nutrient solution is absorbed through minute hairs (trichomes) on the leaf surface through the stomata, even though the latter is not the major pathway. Most of the absorption takes place by diffusion through the cuticle (Salisbury and Ross, 1992). This is in contrast to soil applied fertilizer which is usually in powder or granular form which has to be dissolved by moisture from rainfall or irrigation to be available to plants via the roots. In other words, soil applied fertilizer has to dissolve into the soil solution to be available. When soil applied fertilizers are not readily available or insufficient, foliar feeding is usually practiced or used as supplement (Abbas and Ali, 2011). Chemical residues in the soil and its subsequent ground water pollution as a result of excessive use of fertilizers can be resolved by the use of small amounts of foliar applications to increase growth and yield in wheat (Sabir *et al*., 2002b). The use of both foliar and soil application of NPK have been found to increase grain yield in maize (Ghaffari *et al*., 2011) and pods/plant, seeds/pod and seed weight in lentil (Hamayun *et al*., 2011). Silicon and boron foliar applications had also been used by Ahmed *et al*. (2008) on saline soils to hasten growth, yield and nutrient uptake in wheat. Sabir *et al*. (2002a) also used foliar application of nitrogen to increase vegetative and reproductive growth and development in barley. Afifi *et al*. (2011) used urea foliar application with the aim of minimizing soil applied fertilization of maize to reduce water pollution. Ben Dkhil *et al*. (2011) also found out that foliar potassium fertilization significantly increased vegetative growth of potato but not tuber numbers and yield.

Nitrogen is one of the macronutrients which is required in relatively high quantities for good vegetative and reproductive development in maize. It is a component of protein and nucleic acids and when it is inadequate, growth is reduced (Adediran and Banjoko, 1995). It forms part of many important compounds like chlorophyll and enzymes responsible for many physiological processes in the plant. Nitrogen serves as an intermediary in the utilization of phosphorus, potassium and other elements in plants (Brady and Weil, 2007). Phosphorus also has many vital functions in photosynthesis, utilization of both sugar and starches and in energy transfer processes. Young plants absorb phosphorus very rapidly, to provide rapid, extensive growth of roots. Onasanya *et al*. (2009) have stated that fruit ripening can be hastened by phosphorus when there is excessive application of nitrogen fertilizer in the soil. Potassium also acts as an activator of many enzymes in plant metabolism and provides the ionic background for the maintenance of the living entity of the plant cell (White and Collins, 1982).

In Ghana, foliar fertilization is relatively new. It is currently restricted to the application of micronutrients on few vegetable crops, such as tomatoes and chilli pepper. Considering the benefits of foliar fertilization cited in the literature, there was the need to evaluate in field trials, the new organic FF "Natural Asontem" on the economically important crop such as maize in Ghana. High fertilizer prices along with low produce prices of farm commodities are serious challenges to farmers in Ghana (Wiredu *et al*., 2010). However, Das *et al*. (2010) have observed that farmers' primary interest is in cost of production and return since they show them the relationship between input and output of their enterprises and the unit cost between less and more efficient farming practices. Therefore, it is necessary to conduct cost-benefit analysis of new technologies before any meaningful recommendation can be made to farmers. The objectives of the trials were to: (1) determine the appropriate dosages for application of the foliar fertilizer on maize for optimum growth and yield performance and (2) assess the economic feasibility of the product.

MATERIALS AND METHODS

Field trials were conducted at Kwadaso and Ejura in the forest and forest-savannah transition agro-ecology of Ghana in 2009 and 2010. In the first year different rates of the organic foliar fertilizer alongside with the recommended inorganic fertilizer rate were evaluated. In the second year NPK (15-15-15) was applied as starter in combination with different foliar fertilizer rates on the maize. The experimental design was a randomized complete block with three replications per site. A plot size of 6 rows, 5 m long was used with plant spacing of 80×40 cm. Weeds on the plots were controlled when necessary throughout the experimental period. Soil samples were taken from each location at soil horizons of 0-15 and 16-30 cm depth for analysis before sowing of each trial. Soil chemical analyses at Kwadaso and Ejura (Table 1) indicated that soils were acidic with pH range of 5.4-5.66 and low in Nitrogen (0.02-0.07%) and organic matter (0.28-1.02%) at both locations. However, phosphorus level was high at Kwadaso (39.86-68.09 ppm) and low at Ejura (5.50-8.13 ppm) while potassium level was low at Kwadaso (13.39-30.13 ppm) and moderate (30.13-66.96 ppm) at Ejura (Royal Tropical Institute, 1984).

The treatments for the two years were as follows:

- Treatment combinations in 2009:

T_1: 2 g L^{-1} of foliar fertilizer at 2 and 4 weeks after planting (WAP)
T_2: 2 g L^{-1} of foliar fertilizer at 2, 3 and 4 WAP
T_3: 2.5 g L^{-1} of foliar fertilizer at 2 and 4 WAP
T_4: 2.5 g L^{-1} of foliar fertilizer at 2, 3 and 4 WAP
T_5: 3 g L^{-1} of foliar fertilizer at 2 and 4 WAP
T_6: 3 g L^{-1} of foliar fertilizer at 2, 3 and 4 WAP
T_7: 38:38:38 kg ha^{-1} N: P_2O_5: K_2O at planting plus 3 g L^{-1} foliar fertilizer at 3 WAP
T_8: 38:38:38 kg ha^{-1} N: P_2O_5: K_2O at planting plus 52 kg ha^{-1} N from sulphate of ammonia at 4

- Treatment combinations in 2010:

T_1: No fertilizer application (control)
T_2: 3 g L^{-1} at 2, 3 and 4 weeks after planting (WAP)
T_3: 38:38:38 kg ha^{-1} (NPK) at planting plus 3 g L^{-1} at 2, 3 WAP
T_4: 6 g L^{-1} at 2, 3 and 4 WAP
T_5: 38:38:38 kg ha^{-1} (NPK) at planting plus 6 g L^{-1} at 2, 3 WAP
T_6: 9 g L^{-1} at 2, 3 and 4 WAP
T_7: 38:38:38 kg ha^{-1} N: P_2O_5: K_2O at planting plus 9 g L^{-1} at 2, 3 WAP
T_8: 38:38:38 kg ha^{-1} N: P_2O_5: K_2O at planting plus 52 kg ha^{-1} N from sulphate of ammonia at 4

where, WAP is recommended fertilizer application for maize in the project area.

Table 1: Chemical properties of soils at Kwadaso and Ejura sites

Location	Soil horizon (cm)	pH (H_2O)	Total N (%)	Organic matter (%)	P (ppm)	K (ppm)
Kwadaso	0-15	5.40	0.07	1.02	68.09	30.13
	16-30	5.40	0.04	0.74	39.86	13.39
Ejura	0-15	5.52	0.02	0.34	8.13	66.96
	16-30	5.66	0.02	0.28	5.50	30.13

Statistical and economic analysis: Data on plant stand establishment and days to 50% anthesis and silking, plant height were taken and grain yield was calculated at 15% moisture content. GenStat 5 Release 3.2 (PC/Windows 95) was used for all statistical analyses. Where the ANOVA showed significant differences ($p<0.05$) of variables (e.g., days to 50% anthesis and silking, grain yield, etc.) between treatments the standard error of difference of means (SED) were used to compare between treatments.

Partial budgeting was used to calculate the total costs that vary and the net benefits of the various fertilizer treatments. Grain yields from these researcher managed trials were adjusted down by 10% to conform to farmer management (CIMMYT, 1988). The marginal rate of return (MRR) was calculated as the marginal net benefit (i.e., the change in net benefits between treatments) divided by the marginal cost (i.e., the change in costs), expressed as a percentage. Recommendation was made based on the agronomic results and the comparisons of the rates of return between treatments to the minimum rate of return acceptable to farmers.

RESULTS

In 2009 when application rate of Foliar Fertilizer (FF) was increased from 2 g L^{-1} at 2 and 4 WAP to 3 g L^{-1} at 2, 3 and 4 WAP, grain yield of maize increased by 44% (1320 to 1898 kg ha^{-1}). When 38:38:38 kg ha^{-1} NPK was applied at planting, followed by 3 g L^{-1} FF at 2 and 3, grain yield increased further by 21% (Table 2). However, the recommended chemical fertilizer rate 90:38:38 kg ha^{-1} NPK out-yielded the highest rate of FF by 36% (1898 to 2588 kg ha^{-1}). The trend was similar in 2010 and the recommended fertilizer rate significantly ($p<0.05$) out-yielded the FF applications and the combination of 38:38:38 kg ha^{-1} NPK plus 9 g L^{-1} FF at 2 and 3 WAP across locations by 55% (Table 3). The combination of NPK and higher rate of FF (9 g L^{-1}) was better than the lower combinations of 3 and 6 g L^{-1} (Table 3).

In 2009 plants which received only FF tasseled at 57 day which was 1 to 4 days later than the other treatments, even though it was not significantly ($p<0.05$) different. However, significant differences were observed between treatments in days to 50% silking (Table 2). Plants which received only FF took longer time to silk (60-67 day) than those which received NPK (57-58 day). Anthesis-silking interval was also longer for the sole FF (6-12 day) than those plants which received NPK (4 day). However, in 2010 there were no significant differences between treatments in anthesis and silking (Table 4). Plants which received NPK+FF were taller than those which received only FF. Plants that received the recommended fertilizer application were significantly taller than those that received only FF (Table 4).

Table 2: Grain yield, plant density, days to 50% anthesis (DFA) and silking (DFS) of maize planted in the major season of 2009 at Kwadaso

Treatment	Plants (m^{-2})	Yield (kg ha^{-1})	DFA	DFS
2 g L^{-1} FF at 2 and 4 WAP	3.368	1320	55.0	67.0
2 g L^{-1} FF at 2, 3 and 4 WAP	4.132	1582	56.0	66.0
2.5 g L^{-1} FF at 2 and 4 WAP	4.618	1383	55.0	63.0
2.5 g L^{-1} FF at 2, 3 and 4 WAP	3.889	1830	54.0	60.0
3 g L^{-1} FF at 2 and 4 WAP	4.514	1376	55.0	62.0
3 g L^{-1} FF at 2, 3 and 4 WAP	4.201	1898	54.0	60.0
NPK + 3 g L^{-1} FF at 3 WAP	5.104	2288	54.0	58.0
NPK + ammonium sulphate	4.167	2588	53.0	57.0
Mean	4.249	1783	54.0	62.0
SED	0.434	438	0.9	1.9

Table 3: Grain yield plant density of maize planted under different foliar and chemical fertilizer regimes at Kwadaso and Ejura in 2010

	Kwadaso		Ejura		Across	
Treatment	Plants m^{-2}	Yield (kg ha^{-1})	Plants m^{-2}	Yield (kg ha^{-1})	Plants m^{-2}	Yield (kg ha^{-1})
No fertilizer application	4.500	1637	3.958	1868	4.229	1753
3 g L^{-1} FF at 2, 3 and 4 WAP	4.000	1288	3.437	2119	3.719	1704
NPK+3 g L^{-1} FF at 2, 3 WAP	4.188	1492	3.576	2214	3.882	1853
6 g L^{-1} FF at 2, 3 and 4 WAP	3.938	1401	3.576	2029	3.757	1715
NPK+6 g L^{-1} FF at 2, 3 WAP	4.000	2041	3.368	2294	3.684	2168
9 g L^{-1} FF at 2, 3 and 4 WAP	3.813	1651	3.889	2424	3.851	2038
NPK+9 g L^{-1} FF at 2, 3 WAP	4.375	2355	4.340	3002	4.358	2679
NPK + ammonium sulphate	4.688	3995	4.444	4298	4.566	4145
Mean	4.188	1983	3.824	2531	4.006	2257
SED	0.31	210	0.746	584	0.510	369

Table 4: Mean days to 50% anthesis (DFA) and silking (DFS) and plant height of maize planted under different foliar and chemical fertilizer regimes across Kwadaso and Ejura in 2010

Treatment	DFA	DFS	Plant height (cm)
No fertilizer application	56.0	64.0	210.0
3 g L^{-1} FF at 2, 3 and 4 WAP	57.0	64.0	204.0
NPK+3 g L^{-1} FF at 2, 3 WAP	53.0	63.0	212.0
6 g L^{-1} FF at 2, 3 and 4 WAP	57.0	63.0	204.0
NPK+6 g L^{-1} FF at 2, 3 WAP	56.0	63.0	220.0
9 g L^{-1} FF at 2, 3 and 4 WAP	57.0	63.0	219.0
NPK+9 g L^{-1} FF at 2, 3 WAP	54.0	64.0	230.0
NPK + ammonium sulphate	54.0	62.0	242.0
Mean	55.0	63.0	216.0
SED	2.7	1.0	10.7

Table 5: Partial budget for eight maize fertilizer treatments in 2010

	Treatments for 2010							
Parameters	1	2	3	4	5	6	7	8
Mean yield of maize (kg ha^{-1})	1753.0	1704.00	1853.0	1715.0	2168.0	2038.00	2679.0	4145.0
Adjusted yield (kg ha^{-1})	1578.0	1534.00	1668.0	1544.0	1951.0	1834.00	2411.0	3731.0
Gross field benefits (GH ¢/ha)	946.8	1920.40	1000.8	926.4	1170.6	1100.40	1446.6	2238.6
Cost of foliar fertilizer	-	29.25	19.5	58.5	39.0	87.75	58.5	-
Cost of NPK (15-15-15)	-	-	275.0	-	275.0	-	275.0	-
Cost of sulphate of ammonia	-	-	-	-	-	-	-	200.0
Cost of fertilizer application	-	75.00	75.0	75.0	75.0	75.00	75.0	50.0
Total cost that vary (GH ¢/ha)	-	104.25	369.5	133.5	389.0	162.75	408.5	525.0
Net benefits (GH ¢/ha)	946.80	816.15	631.3	792.9	781.6	937.65	1038.1	1713.6
		D*	D*	D*	D*	D*		

1 US $: GH¢1.50, D* indicates dominated treatments

The partial budget for the various treatments (Table 5 and 6) showed that the net benefit for no fertilizer application (GH¢946.8) was higher than all the sole FF treatments except NPK+1.8 kg ha^{-1} FF at 2 and 3 weeks (GH¢1038.10) and the recommended rate (GH¢1713.60) (Fig. 1). Treatments which had net benefits less than or equal to those of treatments with lower

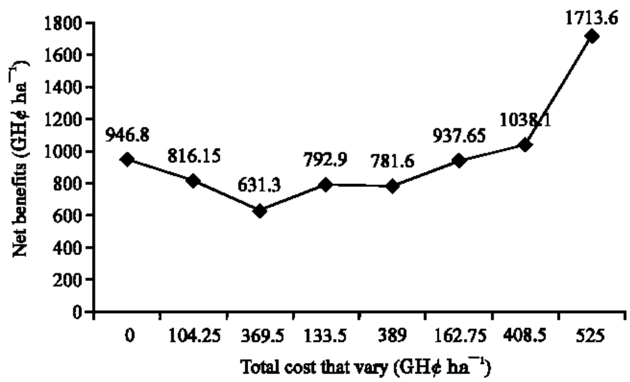

Fig. 1: Relation between total costs that vary and net benefits of eight different fertilizer treatments on maize in 2010

Table 6: Data for partial budget

Item or operation	Rate	Price
Recommended application rate of NPK (15-15-15)	5 bags*/ha	GH¢ 275.00
Recommended application rate of Sulphate of ammonia	5 bags*/ha	GH¢ 200.00
3 g L^{-1} foliar fertilizer at 2, 3 and 4 WAP at GH¢ 16.25 kg^{-1}	0.6 kg ha^{-1}	GH¢ 29.25
3 g L^{-1} foliar fertilizer at 2 and 3 WAP at GH¢ 16.25 kg^{-1}	0.6 kg ha^{-1}	GH¢ 19.50
6 g L^{-1} foliar fertilizer at 2, 3 and 4 WAP at GH¢ 16.25 kg^{-1}	1.2 kg ha^{-1}	GH¢ 58.50
6 g L^{-1} foliar fertilizer at 2 and 3 WAP at GH¢ 16.25 kg^{-1}	1.2 kg ha^{-1}	GH¢ 39.00
9 g L^{-1} foliar fertilizer at 2, 3 and 4 WAP at GH¢ 16.25 kg^{-1}	1.8 kg ha^{-1}	GH¢ 87.75
9 g L^{-1} foliar fertilizer at 2 and 3 WAP at GH¢ 16.25 kg^{-1}	1.8 kg ha^{-1}	GH¢ 58.50
Cost of granular or foliar fertilizer application	Per hectare	GH¢ 25.00
Field price of maize	Per kilogram	GH¢ 0.60

*Weight of a bag of fertilizer = 50 kg

Table 7: Marginal analysis of the three un-dominated treatments

Treatments	Total cost that vary	Marginal cost	Net benefit	Marginal net benefit	Marginal rate of return (%)
Treatment 1 (No fertilizer application)	-	-	946.80	-	-
Treatment 7: (38:38:38 kg ha^{-1} NPK+1.8 kg/ ha at 2 and 3 weeks)	408.50	408.50	1038.1	91.30	22
Treatment 8: (38:38:38 kg ha^{-1} NPK+52 kg ha^{-1} N from ammonium sulphate)	525.00	116.50	1713.6	675.50	580

costs that vary are designated 'D' because they were dominated and do not represent a feasible option to the farmer or producer (CIMMYT, 1988). The Marginal Rate of Return (MRR) for changing from no fertilizer application to NPK+9 g L^{-1} FF at 2 and 3 weeks and then to NPK+Sulphate of Ammonium (SA) were 22 and 580%, respectively (Table 7). This means that for each GH¢100 ha^{-1} on average invested in the combination of NPK+FF, by a farmers who previously was not applying any fertilizer, they will recover their GH¢100, plus an extra GH¢ 22 ha^{-1}. Similarly, for each GH¢100 ha^{-1} on average invested in the combination of NPK+SA, by farmers who previously were applying combination of NPK+FF, then they will recover their GH¢100, plus an extra GH¢ 580 ha^{-1}.

DISCUSSION

The result of the soil chemical analyses (Table 1) indicated low Nitrogen (0.02-0.07%) and organic matter (0.28-1.02%) levels at both locations of the trial and therefore response of the maize to nitrogen application was imminent. However, response to N was clearly pronounced only from the recommended chemical fertilizer rate for maize in Ghana of 90:38:38 kg ha^{-1} (NPK) and partially from the combination of NPK (38:38:38 kg ha^{-1}) plus a high dose of 9 g L^{-1} of FF (Table 2, 3). The dosage of the FF could not be increased beyond 9 g L^{-1} because it tended to scorch the maize leaves. Gooding and Davies (1992) have stated that additives which reduce the accumulation of spray within the leaf and applying in finer rather than coarser sprays can reduce leaf bleaching but mechanisms of damage require further study by scientists.

The response of maize to foliar fertilizer in the present investigation is similar to the findings of Hamayun *et al.* (2011) who worked on the effect of foliar and soil application of NPK on yield components of lentil. They recorded best results from plants treated with NPK through both soil and foliage and also found that soil application produced slightly improved results compared to sole foliar application. Results from the present investigation also confirm the conclusion by Liang and Silberbush (2002) that foliar fertilizer may partially compensate for insufficient uptake by the roots of maize, because the leaf area of the maize crop at the time of spraying might not be large enough to hold the liquid fertilizer in place to make it effective. Jamal *et al.* (2006) working on the effect of soil and foliar application of NPK and ammonium sulphate on wheat also got a similar result. They found out that number of fertile tillers per plant, number of grains per spike and 1000 grain weight increased when NPK was applied both through foliar sprays and in the soil. Soil application of fertilizer also gave higher yields than just foliar sprays of NPK on Wheat. The organic foliar fertilizer Natural Asontem in the present investigation improved yield substantially only when in combination with inorganic fertilizers applied in the soil. However, the recommended chemical fertilizer rate for maize of 90:38:38 kg ha^{-1} (NPK) out-yielded even the combination of NPK (38:38:38 kg ha^{-1}) plus a high dose of 9 g L^{-1} of the FF.

Among the most commonly deficient elements in the soil are nitrogen, phosphorus and potassium which maize requires in adequate supply for good growth and high yield. Onasanya *et al.* (2009) have stated that the quantity of these nutrients required depends on the initial chemical properties of the soil. The initial soil analysis from the present investigation indicated that N, P and K were not adequate in the soil for optimum maize growth. Ghaffari *et al.* (2011) got higher grain yield and economic returns in their integrated nutrient evaluation by combining the recommended NPK application with one spray of multi-nutrient fertilizer which contained both macro and micro nutrients. However, the composition of the foliar fertilizer in the present investigation was made up of just 6.4% w/w soluble organic azote (N) plus 6.4% w/w Organic Nitrogen and 22.0% w/w Organic carbon (C). It did not contain potassium and phosphorus which are two of the three macronutrients essential for proper growth and development of maize. The foliar fertilizer also excluded essential micro nutrients in its composition hence, its poor performance as compared to the inorganic fertilizer treatments. Sharief *et al.* (2006) also increased the grain yield of rice in alkaline soils with blue-green algae bio-fertilizer plus the foliar fertilizer House Green which contained 20% each of N, P and K plus 0.5% each of Zn, Fe, Mg, Cu, 0.02% Bo and 0.05% Mo. Abbas and Ali (2011) also increased the vegetative growth, total number of fruits and dry calyces yield of two cultivars of roselle by applying 2 g L^{-1} of foliar fertilizer which contained not only N but also P and K. Even though P level at Kwadaso in the present investigation was high (39.86-68.09) it could not support the FF alone to give high maize yield in

3 split applications because as much as 80% of P in the soil can be in the insoluble organic form (White and Colhns, 1982). And even much of the soluble form added in fertilizers quickly react with iron, aluminum, clay, organic matter and carbonates and becomes unavailable to plants. The soil pH at both locations of the trial was acidic (5.4-5.66) and could have also caused phosphorus and magnesium unavailability (Lafitte, 1994) in the soils with no NPK treatments.

Das *et al.* (2010) have stated that detailed information on cost and return is a prerequisite for adoption of technical innovation by farmers so that they can choose the right combination of resources or enterprises. From Table 5 and Fig. 1, it is clear that only three options were not dominated and therefore these were subjected to marginal analysis (Table 7). The other treatment options were eliminated because they were economically not feasible. Experience and empirical evidence have shown that for the majority of situations the minimum rate of return acceptable to farmers will be between 50 and 100% (CIMMYT, 1988). Farmers who were not applying fertilizer or using only FF need to take a risk to change to the combination of NPK+FF or even the better option of NPK+Sulphate of Ammonia, therefore the minimum acceptable rate of return was estimated at 50%. Therefore, only the option NPK+Sulphate of Ammonia with MRR of 580% was above the acceptable rate of return and was more likely to be accepted by farmers. Farmers will be reluctant to adopt the combination of NPK+FF because the MRR from changing from no fertilizer to that option was too low at 22%.

Even though yield trends were similar, the mean grain yield in 2010 was lower (1983 kg ha^{-1}) at Kwadaso than that obtained at Ejura (2531 kg ha^{-1}) due to environmental variability. To show that even in unfavourable environmental conditions NPK+SA was the best option, a minimum returns analysis was done by using only yield data from Kwadaso. The trends for the net benefits for the fertilizer treatments were similar to that in Table 5. The net benefit for no fertilizer application was still appreciably lower (GH¢883.80) than that for NPK+SA which was GH¢1682.60.

Crop yield is not the only element of the partial budget that is likely to vary. Input and product prices are also subject to changes from year to year due to the rate of inflation, different markets and government policy. The best way to test a recommendation for its ability to withstand price changes is through sensitivity analysis (CIMMYT, 1988). This involves redoing a marginal analysis with alternative prices which may be very cumbersome. Therefore, the maximum acceptable cost of the NPK+SA in order for their application to be economic was rather calculated for convenience. It came out that if the present cost of GH¢525.00/ha of the combination of the inorganic fertilizer NPK+SA (Table 5) increases to more than GH¢1,351.00/ha without an accompanying increase in the selling price of maize then this fertilizer application ceases to be economical unless this recommendation is lowered.

CONCLUSION

A good recommendation can be thought of as the practices which farmers would follow, therefore, it must be as efficient as possible. The recommended chemical fertilizer rate for maize of 90:38:38 kg ha^{-1} (NPK) significantly ($p<0.05$) out-yielded even the combination of NPK (38:38:38 kg ha^{-1}) plus a high dosage of 1.8 kg ha^{-1} of Natural Asontem (NA) foliar fertilizer. The foliar fertilizer NA contained only 6.4% soluble nitrogen and no indication of the presence of potassium, phosphorus and the micronutrients. This may have contributed to the relatively poor performance of the organic FF as compared to the inorganic fertilizer treatments. The economic analysis of the treatments also showed that apphcation of Inorganic Fertilizer (IF) alone was more economical than sole foliar fertilizer or in combination with 38:38:38 kg ha^{-1} NPK. The full potential benefit of foliar sprays can be realized if scientists do more research into how to prevent losses of nitrogen from the foliage and also reduce the threat of leaf scorching even under relatively low concentrations of nitrogen.

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REFERENCES

Abbas, M.K. and A.S. Ali, 2011. Effect of foliar application of NPK on some growth characters of two cultivars of roselle (*Hibiscus sabdariffa* L.). Am. J. Plant Physiol., 6: 220-227.

Adediran, J.A. and V.A. Banjoko, 1995. Response of maize to nitrogen, phosphorus and potassium fertilizers in the savanna zone of Nigeria. Commun. Soil Sci. Plant Anal., 26: 593-606.

Afifi, M.H.M., R.K.M. Khalifa and Y.E.D. Camilia, 2011. Urea foliar application as a partial substitution of Soil-applied nitrogen fertilization for some maize cultivars grown in newly cultivated soil. Aust. J. Basic Applied Sci., 5: 826-832.

Ahmed, A.H.H., E.M. Harb, M.A. Higazy and S.H. Morgan, 2008. Effect of silicon and boron foliar applications on wheat plants grown under saline soil conditions. Int. J. Agric. Res., 3: 1-26.

Ben Dkhil, B., M. Denden and S. Aboud, 2011. Foliar potassium fertilization and its effect on growth, yield and quality of potato grown under Loam-sandy soil and Semi-arid conditions. Int. J. Agric. Res., 6: 593-600.

Brady, N.C. and R.R. Weil, 2007. The Nature and Properties of Soils. 14th Edn., Prentice Hall, UK., Pages: 980.

CIMMYT, 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edn., CIMMYT Economics Program, Mexico, DF., ISBN-10: 9686127186, Pages: 79.

Das, A., M. Biswas and N. Mandal, 2010. An economic analysis of stevia (*Stevia rebaudiana* Bert.) cultivation through stem cutting and tissue culture propagule in India Trends Agric. Econ., 3: 216-222.

Ghaffari, A., A. Ali, M. Tahir, M. Waseem, M. Ayub, A. Iqbal and A.U. Mohsin, 2011. Influence of integrated nutrients on growth, yield and quality of maize (*Zea mays* L.). Am. J. Plant Sci., 2: 63-69.

Gooding, M.J. and W.P. Davies, 1992. Foliar urea fertilization of cereals: A review. Nutr. Cycl. Agroecosyst., 32: 209-222.

Hamayun, M., S.A. Khan, A.L. Khan, Z.K. Shinwari, N. Ahmad, Y.H. Kim and I.J. Lee, 2011. Effect of foliar and soil application of nitrogen, phosphorus and potassium on some yield parameters of lentil. Pak. J. Bot., 43: 391-396.

Jamal, Z., M. Hamayun, N. Ahmad and M.F. Chaudhary, 2006. Effects of soil and foliar application of different concentrations of NPK and foliar application of $(NH_4)_2$ SO_4 on different yield parameters in wheat. J. Agron., 5: 251-256.

Lafitte, H.R., 1994. Identifying Production Problems in Tropical Maize: A Field Guide. CIMMYT, Mexico, DF.

Liang, F. and M. Silberbush, 2002. Response of maize to foliar vs. soil application of nitrogen-phosphorus-potassium fertilizers. J. Plant Nutr., 25: 2333-2342.

Onasanya, R.O., O.P. Aiyelari, A. Onasanya, F.E. Nwilene and O.O. Oyelakin, 2009. Effect of different levels of nitrogen and phosphorus fertilizers on the growth and yield of maize (*Zea mays* L.) in Southwest Nigeria. Int. J. Agric. Res., 4: 193-203.

Reickenberg, R.L. and M.P. Pritts, 1996. Dynamics of nutrient uptake from foliar fertilizers in red raspberry (*Rubusidaeus* L.). J. Am. Soc. Hort. Sci., 121: 158-163.

Royal Tropical Institute, 1984. Analytical Methods of the Service Laboratory for Soil, Plant and Water Analysis. Part I: Methods for Soil Analysis. Royal Tropical Institute, Amsterdam, The Netherlands.

Sabir, S., J. Bakht, M. Shafi and W. Ali shah, 2002a. Effect of foliar vs. broadcast application of different doses of nitrogen on wheat. Asian J. Plant Sci., 1: 300-303.

Sabir, S., J. Bakht, M. Shafi, W.A. Shah and N.P. Khan, 2002b. Effect of foliar vs. broadcast application of different doses of nitrogen on barley. Asian J. Plant Sci., 1: 213-215.

Salisbury, F.B. and W.C. Ross, 1992. Plant Physiology. 4th Edn., Wadsworth Publishing Co., Belmont, California, USA., Pages: 682.

Sharief, A.E., S.E. El-Kalla, A.T. El-Kassaby, M.H. Ghonema and G.M.Q. Abdo, 2006. Effect of bio-chemical fertilization and times of nutrient foliar application on growth, yield and yield components of rice. J. Agron., 5: 212-219.

White, W.C. and D.N. Collins, 1982. The Fertilizer Handbook. Fertilizer Institute, Canada, Pages: 274.

Wiredu, N.A., K.O. Gyasi, T. Abdoulaye, D. Sanogo and A. Langyintuo, 2010. Characterization of maize producing households in the Northern Region of Ghana. Country Report Ghana CSIR/SARI-IITA, Ibadan, Nigeria.