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Quantification of the value of improved wheat production options in South-western Uganda

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Abstract

Wheat production technologies that included the use of improved varieties/genotypes and fertilizers at recommended rates were demonstrated in a total of twenty four trials in three consecutive seasons - the first rains of 1999 and 2000 and the second rains of 2000 - in Kabale district of south-western Uganda. The experimental design used was a split-plot design. The main plots were fertilizer treatments while the varieties/genotypes constituted the subplots that were of 16 rows of 4 m length and inter-row spacing of 0.3m. Each farm constituted a replication in each season. Analysis of grain yield showed highly significant differences across the seasons (P=0.0000) and between the genotypes (P=0.0000). The over all grain mean yields ranged from 0.5 to 2.4 t/ha for the local check and the elite genotype UW 400 respectively. There was a significant variety x fertilizer interaction (P=0.0000). Genotype responses to fertilizer ranged from 119% for UW 400 to 158%for K.Chiriku. The elite genotypes UW 400 and UW 309 gave slightly higher yields than the released varieties when grown without fertilizers. The mean marginal rate of returns for changing from the use of local varieties (land races) to improved genotypes was 206% while adopting use of fertilizers gave a mean marginal rate of 50%. These results demonstrated that there is high potential of improving wheat production in the south-western Uganda through the use of improved varieties and appropriate application of fertilizers.

Introduction

Wheat (*Triticum eastivum* L), basically a temperate crop, is adapted to the south western highlands of Uganda in the districts of Kisoro and Kabale, on the hilltops in the Mbarara – Bushenyi area and, in eastern Uganda on the slopes of Mt. Elgon in Kapchorwa, Sironko and Mbale districts. In Kapchorwa wheat is grown on larger farms (>2 ha.) that are mechanized while elsewhere the areas sown are in the order of 0.2 – 2 ha. (Gumisiriza *et al.*, 1993). In all these areas, the crop may be grown twice a year – first cropping season in the year is usually March to July/August (Season A) and the second is August/September to December/January (Season B). Unfortunately, very little additional land is available for expansion of crop production due to the otherwise high cropping intensity in these areas. Thus, increased total production of the crop cannot be realized through area expansion. Currently, average yields of 0.5t ha^{-1} and 1.2t ha^{-1} are realized by small-scale farmers and on the larger mechanized farms respectively.

Wheat production practices in the south-western districts of Kabale and Kisoro have remained "rudimentary" and static ever since the crop was introduced in this area. The seed used is very poor and of very old, usually discarded varieties ("land races"). Seedbed preparation is very inadequate; sowing is by broadcasting, usually at very high seed rates; they practice minimal weeding, if any and, despite the land being highly nutrient deficient, no fertilizers are used.

World wide it has been shown that the use of improved varieties under improved crop management practices gives higher yields and hence economic benefit to the farmers. It is envisaged that adoption of such improved

technologies would lead to farmers' improved household incomes and food security. Therefore, this study was aimed at determining and demonstrating, at farm level, the economic benefits of improved production technologies, especially genotypes and fertiliser application.

Materials and methods

The wheat production technologies tested were improved genotypes and the use of fertilizers. The genotypes used were the released varieties K.Chiriku and Nkungu and the elite lines UW 309, UW 400 and a land race as local check. Fertilizer treatments were constituted by the recommended rate of at 50 Kg ha^{-1} N and 60 Kg ha^{-1} P Kg/ha as NPK and no fertilizer at all as a check. The experimental design used was a split plot design. The main plots were fertilizer treatments while the genotypes constituted the subplots that were of 16 rows of 4 m length and inter-row spacing of 0.3 m. The trials were carried out in three consecutive seasons – the first rain season (March to August) of 1999 and 2000 (1999A and 2000A respectively) and in the second rain season of 2000 (2000A) that trials from September 2000 to February of 2001. The experiments were carried out on six farmers' fields, each farm constituting a replicate in each season. Thus, a total of eighteen trials were carried out. At each site, the other non variable treatments included recommended agronomic practices such as proper seedbed preparation, seed rate of (100 Kg ha^{-1}), hand weeding at least twice (or as was necessary) and bird scaring from anthesis to harvest to minimize losses due to birds. Fourteen middle rows (out of the sixteen) per plot were hand harvested, threshed, cleaned, sun-dried and weighed at approximately 12% moisture content.

All field operations were done and valued by the farmers to avoid the differences that could arise if these operations were carried out by the research scientists. The cost of fertilizers and wheat seed and the farm gate price of wheat grain were recorded.

Analysis of variance was carried out using plot means transformed into to t ha^{-1}. Cost benefit ratio was calculated using methodologies developed by CIMMYT (CIMMYT, 1988) and as outlined by Gittinger (Gittinger, 1981) and Marcelino (1992). During the period of these experiments the cost of wheat grain was constant at Shs 350 Kg^{-1} resulting in Shs 350,000 per ton. The cost of fertilizer (N:P:K - 20:10:10) was Shs 900 Kg^{-1} that transformed into Shs 225,000 ha^{-1}. The cost of improved seed was Shs 800 Kg^{-1} and Shs 350 Kg^{-1} for farmer-saved seed that transformed into Shs 80,000 and 35,000 ha^{-1} for improved seed and farmers' seed (local variety) respectively. At farm level, the cost of applying fertilizer was valued at Shs 20,000 ha^{-1}. Cost of harvesting wheat grain is Shs 10,000 per 100 Kg-bag.

Results

Grain yield of the different genotypes under different fertilizer levels are given in Table 1. Analysis of variance of the yields of the genotypes across the different farms and across seasons is given in Table 2. Highly significant differences (P=0.000) were recorded for grain yield across the different seasons with 1999B having the highest mean grain yield (1.95 t ha^{-1}) while 1999A with a mean yield of 1.47 t ha^{-1} was the lowest. There were no significant differences in mean grain yields between the blocks that represented the different farms. There was a highly significant interaction ((P=0.0000) between the seasons and the blocks.

Table 1: Grain yield (Kg ha^{-1}) of the wheat genotypes under different fertilizer levels averaged at six farms over three seasons (March 1999 – February 2001)

Genotype	Treatment		Mean
	With Fertilizer	Without fertilizer	
UW 400	3.22	1.47	2.35
UW 309	3.17	1.34	2.25
Nkungu	2.89	1.20	2.05
K. Chiriku	2.58	1.00	1.79
Local check	0.70	0.28	0.49
Mean	2.51	1.06	
LSD	0.771		0.1500
S.E.D	0.071		0.0905

Table 2: Analysis of variance of the yield of the different treatments across the three seasons

Source	Df	MS	Pr>F
Total	179		
Seasons (S)	2	4.564	0.0000
Blocks (B)	5	0.197	0.9756
SxB	10	1.321	0.0000
MP (Fert. Levels)	1	1446.97	0.0000
S x MP	2	11.42	0.0000
B x MP	5	0.45	0.8144
SP (genotypes)	4	139.13	0.0000
S x SP	8	1.37	0.2175
B x SP	20	0.52	0.9551
MP x SP	4	21.07	0.0000
Residual	118	0.147	
Grand mean=1.786	R-squared = 0.9267		C.V= 21.50%

There were also highly significant (P=0.000) differences between the fertilizer treatments with fertilizer application resulting into 2.51 t ha^{-1} compared to the check that gave 1.06 t ha^{-1}. Genotypes also exhibited highly significant (P=0.0000) mean yields with UW 400 giving 2.35 t ha^{-1} compared to the local check that yielded only 0.49 t ha^{-1}. There was also a highly significant (P=0.0000) interaction between the fertilizer treatments and the genotypes.

The partial budget of the genotype by fertilizer application rate is given in Table 3.

The total costs that varied range from Shs 63,000 to Shs 647,000 ha^{-1} for the local check with no fertilizer applied and genotype UW 400 with fertilizer applied at the recommended rate respectively. The cost of harvesting was the most variable across the treatments with a range of Shs 28,000 for the local check with no fertilizer applied to Shs 322,000 for genotype UW 400 with fertilizer applied at recommended rate.

Table 3: Partial budget of the genotype by fertilizer application rate experiment

	Treatments									
Genotype	UW 400		309+F		Nkungu		KChiriku		Local Check	
Fertilizer Status	With	Without	With	Without	With	Without	With	Without	With	Without
Average Yield (t/ha)	3.22	1.46	3.17	1.33	2.89	1.20	2.58	1.00	0.70	0.28
Gross field benefits (Shs/ha)	1127000	511000	1109500	465500	1001000	420,000	903000	350000	245,000	98,000
Cost of seed	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	35,000	35,000
Cost of fertilizer (Shs/ha)	225,000	0	225,000	0	225,000	0	225,000	0	225,000	0
Cost of applying fertilizer	20,000	0	20,000	0	20,000	0	20,000	0	20,000	0
Cost of harvesting (Shs/ha)	322,000	146,000	317,000	133,000	289,000	120,000	258,000	100,000	70,000	28,000
Total variable costs (Shs/ha)	647,000	226,000	642,000	213,000	614,000	200,000	583,000	180,000	395,000	63,000
Net benefits (Shs/ha)	480,000	285,000	467,000	252,500	387,000	220,000	320,000	170,000	-150,000	35,000

The scenario of comparing the effect of fertiliser application versus no fertilizer application is shown in Table 4. Although the overall mean benefits of applying fertilizer appear higher, the magnitude of the difference is lowered by the negative benefits accruing from application of fertilizer while using the local check (genotype).

Table 4: Net benefits in Shs ha^{-1} by genotype for treatments recommended fertilizer applied and no fertilizer

Genotype	Benefits at recommended fertilizer	Benefits with no fertilizer
UW 400	480,000	285,000
UW309	467,000	252,500
Nkungu	387,000	220,000
K.Chiriku	320,000	170,000
Local check	-150,000	35,000
Genotype averages	300,800	192,400

A dominance analysis for genotype by fertilizer rate was carried out(Table 5) as a response to the observation that Treatment 9 gave lower net benefits than Treatments 10, 8, 6, 4 and 2. Treatment 9 was found to be dominated and subsequently eliminated from further considerations as can be seen in Table 6 for marginal analysis. Considering individual treatments, the marginal rate of return for changing from use of local variety to improved genotypes is 115% (Table 6). Thus for every shilling invested in use of improved genotypes a farmer can expect to recover the Shs.1.00 and obtain an additional Shs. 1.15. Similarly, a farmer could expect to get Shs 2.50 more if he/she adopted higher yielding varieties.

Among the improved genotypes, marginal rate of return for changing to use of fertilizers at recommended rates was 37 % for K.Chiriku, 40% Nkungu, 46% for UW 400 and 50 % for UW 309.

Table 5: Dominance analysis, genotype by fertilizer application rate

Treatment	Genotype	Fertilizer rate (+ or -)	Total costs that vary (Shs/ha)	Net benefits (Shs/ha)
10	L Check	-	63,000	35,000
8	K Chiriku	-	180,000	170,000
6	Nkungu	-	200,000	220,000
4	UW 309	-	213,000	252,500
2	UW 400	-	226,000	285,000
9	L Check	+	395,000	-150,000 ***D**
7	K Chiriku	+	583,000	320,000
5	Nkungu	+	614,000	387,000
3	UW 309	+	642,000	467,000
1	UW 400	+	647,000	480,000

***D** Dominated treatment

A summary of the benefits of the use of improved genotypes versus land races represented in this experiment by local check and fertilizer use versus no fertilizer is given in Table 7. Adopting the use of improved genotypes implies a 260% rate of return while adopting use of fertilizers implies a 50% rate of return.

Table 6: Marginal analysis, genotype by fertilizer application rate experiment

Treatment	Variable costs (Shs/ha)	Marginal costs (Shs/ha)	Net benefits (Shs/ha)	Marginal net benefits (Shs/ha)	Marginal rate of return (%)
L Check – F	63,000	35,000	117,000	135,000	115.4
KChiriku – F	180,000	170,000	20,000	50,000	250.0
Nkungu – F	200,000	220,000	13,000	32,500	250.0
UW 309 – F	213,000	252,500	13,000	32,500	250.0
UW 400 – F	226,000	285,000	357,000	35,000	9.8
K Chiriku+F	583,000	320,000	31,000	67,000	216.1
Nkungu +F	614,000	387,000	28,000	80,000	285.7
UW 309 +F	642,000	467,000	5,000	13,000	260.0
UW 400 +F	647,000		480,000		

Discussion

Variation in grain yields over the seasons could have been due to environmental factors. 1999A season, the season that had the lowest mean grain yields experienced a long dry spell with a total amount of rain of only 92.6 mm that was realised in the months of April and May while June and July received no rain at all. Such conditions were responsible for the poor grain filling and overall low yields in the district. On the other hand, 1999B and 2000A received 289.2 mm and 189.8 mm of rain during the duration of four months for the wheat crop to be sustained. In these latter seasons, the rain was well spread with tapering amounts in the last month to allow for proper drying, harvesting and threshing of the crop.

Whereas there were no significant differences between the blocks (farms), there was a highly significant interaction between the seasons and the blocks. This latter scenario could have arisen as a result of using different fields in different farms in different seasons. The farmers were not obliged to use the same fields every season.

The observed highly significant differences between the main plots, fertilizer treatments, were expected. The soils in Kabale district are known to be highly nutrient deficient (Govt. O. Uganda, 1995) and hence any appropriate

Table 7: Combined marginal analysis, local check by improved genotype and fertilizer usage against no fertilizer usage

Treatment	Variable Costs (Shs/ha)	Marginal Costs (Shs/ha)	Net benefits (Shs/ha)	Marginal net benefits (Shs/ha)	Marginal Rate of return
L Check (land race	229,000	-57,500	184,125	379,500	206%
Improved genotypes	413,125		322,000		
No fertilizer	176,400	192,500	445,100	221,000	49.7%
Fertilizer applied	621,500		413,500		

soil nutrient amendments would result in increased yields. Similarly, the variations between the genotypes were a reflection of the improvements being made in the wheat breeding programs both at national (Wagoire *et al.*, 2002) and international level (Rajram *et al.*, 1988). The local check that was used was a "land race", the varieties K.Chiriku and Nkungu are now relatively old varieties that were released in Uganda in 1995, while the genotypes UW 400 and UW 309 are among the newer germplasm developed at CIMMYT. The superiority of UW 400 and UW 309 is in agreement with previous work (Wagoire *et al.*, 2002). The newer germplasm has had a lot of good traits incorporated in them among which are high yields, disease resistance and high responsiveness to nutrient applications.

As shown in Tables 4, 6 and 7 application of fertilizers at recommended rates resulted in increased yields and benefits except when the local check was used. The apparent lack of positive response to fertilizer by the local check is not surprising. The local check (land race) was characterised by being very tall and with weak stems that led to very early lodging in those plots that fertilizer had been applied. Such conditions naturally lead to low yields as grain filling is inadequate due to the effects of early lodging. Furthermore, the local check was very susceptible to yellow rust and stem rust. These diseases like the early lodging result in poor grain filling and consequently low yields. Such are the conditions that led to treatment 1 (Local check + fertilizer) being dominated (Table 5).

The marginal rate of returns (Table 6 and 7) suggest that investment in adapting improved genotypes and application of fertilizers is beneficial. Improved wheat genotypes however, seem to have a higher marginal rate of returns (206%) while the use of fertilizer would result in a marginal rate of return of about 50%. While comparing performance of improved genotypes the marginal rate of return for changing to use of fertilizers ranges from 37% for K.Chiriku to 50% for UW309. This rate may seem small, but considering that a wheat crop takes 3 to 4 months to mature and in Uganda the fluctuations in the price of wheat grain are never drastic, these seemingly low rates of returns are acceptable. In addition, however, to a farmer the change to use of fertilizers to complement the change to use of improved genotypes would be attractive.

In effect, therefore, while a farmer would be recommended to put his first shilling of investment in accessing and using improved genotypes, it would be an added advantage if he in addition used fertilizers.

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