WHEAT AND BARLEY RESEARCH IN THE SOUTHERN HIGHLANDS OF TANZANIA: A REVIEW OF PAST PROGRESS AND A FOCUS ON THE FUTURE

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ABSTRACT

Research on wheat and barley began at UAC in the early 1970s with an emphasis on breeding for improved high yielding varieties and on the development of agronomic recommendation packages. the continuous flow of improved varieties resulting from this effort has increased production on both large and small scale farms in the Southern Highlands. Research findings indicate that the genetic yield potential of currently available varieties is 5 t ha^{-1} for wheat and 4.5 t ha^{-1} for barley. However, yields in farmer's fields are generally still very low, as a result of technological and socio-economic constraints at farmer level. The recommendation packages have been developed with the objective of alleviating some of these constraints but transfer of this technology to the rural farming community has been slow. In future the wheat and barley research programme plans to put greater emphasis on village on-farm trials and demonstrations, as one way of enhancing the adoption of currently available technology.

INTRODUCTION

Wheat *(Triticum aestivum)* and barley *(Hordeum vulgares)* were introduced into Tanzania at almost the same time, towards the end of the nineteenth century. Triticale, a recent crop, was introduced into the country in the 1970s. Wheat has gained in importance as a food crop, and now ranks fifth among the cereal crops grown in Tanzania (Sariah and Mrimi, 1987). In the Southern Highlands it ranks third after maize and rice. Barley ranks the sixth after wheat among the cereal crops grown in Tanzania and is mainly used for malt production by the brewing industry. The national requirement for malt barley is 16,000 t per year. Local production meets only 22-42% of this requirement, so that imports are necessary to fill this production gap (Kisandu, 1991). The total area under wheat and barley in the Southern Highlands has been estimated to be as much as 100,000 ha (Amani *et al.*, 1991), although only 25,000 ha were estimated to be under production in 1991.

There are many constraints to improved production. These include the use of low yielding cultivars, lack of crop rotation, poor land preparation and crop management, and lack of appropriate machinery to support production. Research efforts at UAC have been directed towards finding solutions to some of these problems. The objective of this paper is to review past research on wheat and barley at Uyole Agricultural Centre (UAC) and to outline plans for the future.

RESEARCH REVIEW

Wheat

In the Southern Highlands, organized research work on wheat began in 1972, with the objective of developing genotypes with improved traits, such as high yield potential, good baking quality, wide ecological adaptation and disease resistance. Research on husbandry practices was also initiated in order to develop suitable recommendation packages for exploiting the yield potential of the improved cultivars.

Initial research activities involved the evaluation of wheat varieties, which were introduced from the northern part of the country, for yield and adaptability (Table 1). With time, these varieties were

found to be susceptible to foliar diseases, especially leaf rust, thereby limiting their widespread cultivation in the Southern Highlands. Efforts to replace these cultivars were helped by the introduction of lines from the International Centre for the Improvement of Maize and Wheat (CIMMYT). These lines were screened for yield and disease resistance at a number of locations in the Southern Highlands, and several years later this resulted in the release of Juhudi No. 1, a semi-dwarf early maturing variety with good baking qualities and better yield potential than previously tested cultivars (Table 2). To facilitate the extensive testing of wheat germplasm, the programme has also collaborated with other institutes, in particular the Selian Agricultural Research Institute in Arusha, and the Tanganyika Wattle Company in Njombe.

Screening and evaluation studies have since resulted in the identification of several more promising lines, of which Hahn 'S' may be released soon. Efforts to identify more areas suitable for wheat production have shown that Itala, in the Uporoto mountain range, has good potential for wheat production (Table 3).

Table 1. Yield (kg ha^{-1}) of wheat varieties from northern Tanzania across three locations in the Southern Highlands (Uyole, Igeri and Nkundi), 1975-1982

	1975/76	1976/77	1988/81	1981/82
Tai	1 980	3 020	2 535	1 824
Mbuni	NA	2 820	1 691	1 603
Trophy	1 490	2 060	2 173	1 354
Mamba	2 050	1 130	2 092	1 853

Table 2. Yield (kg ha^{-1}) of wheat cultivars/lines from the International Centre for the Improvement of Maize and Wheat, 1985/86-1987/88

	1985/86	1986/87	1987/88
Juhudi	2 180	3 587	2 650
T.Viri	2 420	2 318	2 605
Vee 'S'	2 073	3 664	2 477
Koel	NA	4 021	1 813
Mbuni	1 694	2 691	1 575

Table 3. Yield (kg ha^{-1}) of wheat varieties at six locations in the Southern Highlands, 1988/89-1989/90

Variety	Uyole	Itala	Nkundi	Mbimba	Igeri	Dabaga
Juhudi	1 849	3 819	2 042	1 224	1 755	1 619
T. Viri	2 323	3 227	2 301	1 684	1 724	1 923
Hahn 'S'	2 696	3 810	2 349	1 772	2 132	1 676
Koel	2 443	4 353	2 028	1 802	1 813	1 766
Pavon	2 059	4 395	2 022	2 346	2 119	1 686
Vee 'S'	2 240	4 420	2 160	2 012	2 298	1 966
LD7831	2 366	3 253	2 220	2 273	1 815	1 736

Barley

Between 1971 and 1974, research into barley was carried out only at Uyole, the headquarters of UAC. Evaluation trials were extended to Sumbawanga, Njombe and Mbozi in 1975 and 1976 and later in 1977, to the farms of Tanzania Breweries Limited (TBL) at Mtanga in Iringa. Since then, collaboration has been maintained with TBL farms, and with Selian Agricultural Research Institute in Arusha and the Tanganyika Wattle Company in Njombe.

Early breeding work started with introductions from Kenya. In 1976 lines from Denmark were introduced to UAC. These were followed by lines/varieties from CIMMYT in 1980 (Mrimi, 1980). From these introductions, selections and a series of evaluations have been made.

Selection and evaluation of imported lines has resulted in the release of a number of varieties suitable for the conditions of the Southern Highlands and other barley growing areas in Tanzania. In the early 1970s, two introduced varieties, Proctor and Research, were grown. These were followed by the introduction of Amani from Kenya, which performed better in Northern Tanzania than in the Southern Highlands, because of its susceptibility to leaf rust. Since 1980, the (local) varieties Kisa, Emma, Halima and Makete No. 1 have been provisionally released to replace older varieties (Table 4).

The breeding programme has plans to initiate a crossing programme in order to minimize introductions, especially those from CIMMYT, which have consistently shown poor malting qualities. However, implementation of these plans has been delayed because of lack of facilities and well trained technical staff.

Table 4. Characteristics of barley varieties developed through selection and evaluation at Uyole Agricultural Centre

	Origin/ source	Year introduced/ released	Maturity	Susceptibility/ resistance[1] to				Potential yield[2]	Malting quality
				LR	Helm	Scald	lodging		
Research	Australia	1950s	Late	R	S	S	S	Low	Fair
Proctor	England	1950s	Late	S	S	VS	VS	Medium	Good
Amani	Kenya	1977	Medium	VS	S	S	VS	Medium	V. good
Kisa	Local release	1980	Medium	R	S	S	S	Medium	Fair
Emma	Local release	1980	Late	R	S	S	S	Medium	Fair
Halima	Local release	1980	Medium	S	S	S	S	Medium	Fair
D579	USA	1980	Late	VS	S	S	S	Medium	Fair
Makete[3] No. 1	Local Release	1987	Medium	R	MS	MS	MS	Medium	Feed barley

Source: UAC (1990); [3]Morris, (1987)

[1]LR, leaf rust; Helm, *Helminthosporium* spp; Scald, *Ryncosporium secalis*, and lodging; R, resistant; MS, moderately susceptible; S, susceptible; VS, very susceptible. [2]Low, <2 t ha^{-1}; medium, 2-3.5 t ha^{-1} and; high,> 3.5 t ha^{-1}.

AGRONOMY

Poor agronomic practices have been the main factor contributing to low wheat and barley yields in the Southern Highlands. In order to exploit the yield potential of improved varieties, research has been done to develop suitable agronomic recommendation packages for the different agro-ecological zones where these crops are important.

In general, agronomic recommendations for both wheat and barley are similar and they were therefore handled together and are reported together here except where recommendations differ.

Fertilizer application

General recommendations on the economic levels of fertilizer to apply to wheat and barley have been developed, and research is continuing on the formulation of the requirements for nitrogen and phosphorus in specific agro-ecological zones.

The previous recommendation of a ratio of nitrogen to phosphorus of 2:1 is still considered to be the most economical in many wheat and barley growing areas of the Southern Highlands, with optimum yields obtained at the rate of 50 kg N and 20-25 kg P ha^{-1} (UAC, 1986/87-1988/89). Recent studies have shown that a slight yield increase can be obtained if the rate of phosphorus is increased to 40 kg ha^{-1} (Table 5).

Micronutrient studies have shown that copper is essential in areas with volcanic soils in the Southern Highlands. Studies conducted at UAC have shown that the response of wheat and barley to nitrogen and phosphorus fertilizers is increased if 20-40 kg ha^{-1} of copper sulphate is also applied. For soils that are deficient in copper, this treatment lasts for five years. Application of Blitox (copper oxychloride) as a foliar spray at the rate of 1-2 kg ha^{-1} is also effective. Under some circumstances, for example in the absence of spraying facilities, copper may be applied as a seed dressing, although this is a less effective. A combination of copper seed dressing and foliar spraying is more effective than either form of application alone (Table 6), although the economics of this practice are still under investigation.

Table 5. Yield response (kg ha^{-1}) of wheat to the application of nitrogen and phosphorus, 1986/87-1988/89

P_2O_5 (kg ha^{-1})	N (kg ha^{-1})			
	0	30	40	60
0	2415	2536	2527	2476
20	2495	2675	2628	3108
30	2464	2760	2777	3250
40	2776	3172	3247	3655

Table 6. Influence of seed dressing and foliar application of copper on yield of wheat

	Yield (kg ha^{-1})
Untreated	2220
Blitox	
Seed dressing at 0.5 kg 100 kg^{-1} seed	3500
Seed dressing at 1.0 kg 100 kg^{-1} seed	3500
Foliar spray at 1.0 kg ha^{-1}	3370
Seed dressing at 0.5 kg 100 kg^{-1} seed + foliar spray at 0.5 kg ha^{-1}	3670
Perenox	
Seed dressing at 0.5 kg 100 kg^{-1} seed	2900
Seed dressing at 1.0 kg 100 kg^{-1} seed	3230
Foliar spray at 1.0 kg ha^{-1}	3430
Seed dressing at 0.5 kg 100 kg^{-1} seed + foliar spray 0.5 kg ha^{-1}	3610

Time of planting

Wheat. Past research findings have shown mid-February to mid-March to be the optimum planting time for wheat (UAC, 1982/83). However, with continuous changes in the varieties used and with diverse agro-ecological conditions, there has been a need to review optimum planting times for new varieties in important wheat growing areas. New time of planting studies are currently going on in order to verify or modify current recommendations.

Barley. Experiments at Mtanga, Iringa (1800 m above sea level) between 1978/79 and 1980/81 have shown that it is risky to plant beyond February because the rains stop earlier at this site, so there can be severe crop failure. At Uyole, optimum planting time has been shown to be early to mid March (Table 7). However, it has been shown that optimum planting time at any site depends on the time to maturity of a variety. Experiments at Uyole (1750 m above sea level) have shown that optimum planting time for late maturing varieties is mid-February to early March, while early maturing varieties could be planted as late as the beginning of April (UAC, 1982/83). Research on appropriate time of planting for new varieties is still continuing.

Table 7. Effect of time of planting on barley yield (kg ha^{-1}) at two sites differing in rainfall patterns (mean of six seasons' data at Uyole and three seasons' data at Mtanga)

	Uyole			Mtanga		
Planting date	15-28 February	1-15 March	16-30 March	11-15 February	16-28 February	1-15 March
Yield	1364	1639	1220	729	692	473

Crop establishment

Thorough seedbed preparation is recommended before wheat or barley is sown, in order to facilitate rapid and even germination. A sowing depth of 4-5 cm in a moist soil is preferable. A seed rate of 100-120 kg ha^{-1} at an interrow spacing of 20-25 cm, achieved by using a seed drill, is the best method. If broadcasting is used, it is advisable to increase the seed rate to 150 kg ha^{-1}.

PLANT PROTECTION

Disease control

In the Southern Highlands, leaf rust, scald, and leaf and glume blotches have been the major factors limiting yield and dependability of wheat and barley (Katunzi, 1988). Early planted wheat or barley normally encounter prolonged cool wet conditions which can intensify the incidence of leaf and glume blotches. Screening of cultivars for tolerance or resistance to diseases is being undertaken as the most feasible approach to crop protection.

Studies to evaluate chemical means of disease control have shown that good control can be achieved obtained with Benlate, Labilite and Tilt 250 EC. Seed dressing with Fernasan D dust has also been recommended (UAC, 1981). The severity of *Septaria* leaf rust, leaf and glume blotches may be minimized by cultural practices, such as avoiding early planting.

Weed Control

Common weeds found in the wheat and barley producing areas of the Southern Highlands are: *Ageratum conyzoides, Spergula arvenis, Cyperus* spp. *Chloris* spp, *Cynodon* spp, *Nicandra phaseoloides* and *Panicum* spp. Yields are normally severely reduced by heavy weed infestation.

Herbicide screening for wheat and barley at UAC has shown that 2.4-D amine or MCPA (2-methyl-4-chlorophenoxy acetic acid) (at 1.2 l ha^{-1}), applied at the four to five crop leaf stage, give

good control of broad leaved weed species. However, because 2.4-D amine is phytotoxic, MCPA is preferable. Recent evaluation trials have shown that Faneron Super 50 WP (bromofenoxim + terbutryn) is a possible alternative to MCPA.

Efficient tillage is the most effective and economical means of weed control for both commercial and small scale wheat and barley production. Morris (1985) proposed a combined chemical and cultural approach to weed control, to limit the build-up of weeds that survive pre-planting tillage. Studies at Uyole Agricultural Centre indicate that timely tillage is more effective and economical than chemical weed control alone. Thorough land preparation at pre-planting time, together with careful choice of sowing date, seed rate, and depth of sowing, and the use of improved high quality weed-free seed, should give a crop maximum competitive advantage against weeds.

ON-FARM RESEARCH

Wheat

Towards the end of the 1980s on-farm research was included among the activities of the wheat and barley research programme, to expedite the transfer of research findings to the farming community, as well as to test and verifying potential recommendation packages under farmers' field conditions.

On-farm trials have been carried out at ten locations, covering Iringa, Mbeya, Ludewa, Makete and Sumbawanga Districts. They have been well received, as farmers have been able to learn about improved varieties and good management and compare these with their traditional cultivars and production practices. There has been an increased demand for improved seeds in the trial areas.

Barley

On-farm trials for barley have mainly been on farms belonging to TBL, or on farms growing barley under contract with TBL. The aim of these trials was to solve problems related to soil fertility, time of planting and foliar diseases, which limit barley production in the Southern Highlands. On small scale farms in the Mporoto and Makete Highlands, on-farm trials have involved feed barley rather than brewing barley. Problems at specific farms have been solved through the on-farm trials approach.

ACHIEVEMENTS AND CONSTRAINTS TO ADOPTION OF TECHNOLOGY

Wheat

Research activities carried out by UAC have led to considerable achievements by small farmers in the Southern Highlands. Where on-farm research trials have been conducted, farmers have realized the need appreciated the benefits of changing from their traditional low yielding cultivars to improved ones, such as Juhudi No. 1 and T. Viri. They have also appreciated the importance of timely planting, the use of fertilizer, optimum seed rates and weed control, although adoption of some of these components has been difficult because rural farming communities have limited financial resources. Researchers at UAC have also succeeded in identifying wheat varieties adapted to non-traditional wheat growing areas like Mbozi in Mbeya Region, where there is now large scale wheat production on the National Agricultural and Food Company (NAFCO) farms.

Despite these achievements, the following constraints still hamper the full and widespread use of wheat and barley production technology generated by UAC.

1. *Government policy.* The lack of sound Government policy on wheat as an important food and cash crop has hindered the increased production of this crop as there have not been many incentives in terms of wheat prices or credit facilities.

2. *Inadequate seed supply.* TANSEED, the Tanzania Seed Company, has not been able to satisfy farmers' seed requirements so farmers have tended to produce and keep their own seed, which is contrary to the Tanzania seed law of 1977. The farmers are unable to produce and maintain pure seed, because they have not been trained to do so. The resulting seed mixtures produce low yields.

3. *Lack of an efficient technology transfer system.* Many extension workers are not well informed about new research findings. This has frustrated researchers' efforts to narrow the yield gap between those from on-station research plots and those from smallholdings.

Barley

Both TBL and small farmers have benefited from the involvement of UAC in barley research, especially through on-farm trials. Improved varieties, such as Kisa and Emma, which are higher yielding and more resistant to leaf rust than the former varieties Proctor and Research, have been released and adopted, and have contributed to increased barley production. Because of the identification of these resistant varieties, leaf rust disease is no longer a problem to barley growers in the Southern Highlands.

Poor malting quality has slowed down the release of improved barley varieties. CIMMYT, the major source of new lines/varieties, places more emphasis on food and feed barley than on malting barley, making it difficult to identify good malting quality varieties from their introductions. Breeding work involving local crosses might solve this problem, although this has so far been restricted by lack of facilities and technical skill.

Inadequate funding of barley research is likely to be a major problem in the near future. If barley research is discontinued there may not be suitable varieties available in the event of new disease outbreaks, and production will decline as a result.

SEQUENCE OF INNOVATIONS

Experience has shown that it is difficult for farmers to adopt whole packages of innovations generated from research. They tend to adopt one component at a time. Financial constraints, labour demands and the perceived risks involved in the adoption process are some of the reason for this approach.

With this in mind, a sequence of innovations for wheat and barley growers in the Southern Highlands of Tanzania to adopt is suggested below and summarized in Table 8. The anticipated yields as a result of the adoption of one recommendation after another are based on field research data collected from different trials in the zone.

1. *Variety.* Although the yield of local varieties can be improved by the use of recommended husbandry practices, a better response will be obtained with improved varieties.

2. *Optimum tillage.* The yield of improved varieties may be increased by the adoption of low cost means of weed control, for example by thorough soil tillage, twice before planting. This minimizes weed competition, especially during germination and early development of wheat seedlings.

3. *Sowing method.* Since many farmers use broadcasting rather than drilling as a sowing method because they lack drilling machinery, a high seed rate of 150 kg ha^{-1} is recommended to achieve an even plant population. Drilling (at a row spacing of 23 cm and with 110 kg seed ha^{-1} will increase yields but requires investment in machinery, which small farmers cannot afford.

4. *Fertilizer.* Used in addition to other agronomic practices, nitrogen and phosphorus fertilizer will further increase yields.

5. *Chemical weed control.* Most small scale farmers combat weeds by thorough soil tillage before sowing. After crop establishment, hand pulling of weeds should be practised if necessary. Although herbicide application involves additional costs, if capital is not a constraint it is an efficient way of controlling weeds and results in increased yields.

6. *Copper application.* Usually, yields of wheat and barley are increased by the application of nitrogen and phosphorus fertilizers, but on young volcanic pumic soils, a response is obtained only when copper is also supplied, as a micronutrient.

Table 8. Suggested sequence of innovations for adoption by smallholder farmers to improve their production of wheat and barley

Management	Characteristics	Anticpated yield (kg ha^{-1})	
		Wheat	Barley
Zero management	Local variety, poor land preparation	400	290
Variety	(i) Local variety, improved practices	1000	1200
	(ii) Improved variety, minimum tillage	1 700	1 600
Optimum tillage	Two tillage operations before planting	2 060	2 000
Sowing method	(i) Broadcasting	2 260	2 100
	(ii) Drilling	2 740	2 500
Fertilizer	Addition of optimal N + P, hand weeding	3 320	3 500
Weeding	Use of herbicides	3 960	3 600
Micronutrients	Addition of copper	4250	4500

PRIORITIES AND STRATEGIES FOR FUTURE RESEARCH

Much information has already been gathered with regard to wheat and barley production technology in the Southern Highlands. However, this information has not so far had much impact on farmers in rural communities. Although the generation of new genotypes and agronomic packages will continue, the transfer of currently available technology to smallholders will receive much emphasis. The priorities for future research are therefore as follows.

1. On the basis of past experience, on-farm trials appear to be the most effective tools for the transfer of information about improved wheat and barley technology in the Southern Highlands. On-farm trials should be extended to cover all potential wheat and barley growing areas.

2. Research to identify improved cultivars with high yield potential and disease resistance will continue. However, the emphasis will be on early maturing wheat varieties adapted to warmer climates.

3. Trials to review technological packages for wheat and barley will be planned, to cope with changes in the varieties available, and climatic and edaphic factors.

4. More emphasis will be given to the development of high quality malting barley varieties, involving local crosses using appropriate sources and collections.

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