

## ON-FARM EVALUATION OF ALTERNATIVE BREAD WHEAT PRODUCTION TECHNOLOGIES IN NORTHWESTERN ETHIOPIA

ASMARE YALLEW, D.G. TANNER<sup>1</sup>, REGASSA ENSERMU<sup>2</sup> and ALEMU HAILE

Adet Research Centre, P.O. Box 8, Bahir Dar, Ethiopia

<sup>1</sup>CIMMYT/CIDA East African Cereals Programme,

P.O. Box 5689, Addis Ababa, Ethiopia

<sup>2</sup>Kulumsā Research Centre, P.O. Box 489, Asela, Ethiopia

(Received 13 March, 1995; accepted 4 June, 1995)

### ABSTRACT

Wheat (*Triticum* spp.) is a major crop grown in northwestern Ethiopia. The primary wheat production constraints in this area include low soil fertility, use of unimproved and disease-susceptible varieties, and high weed infestation. Technology packages, combining three nutrient levels (92-20, 41-20 and 0-0 kg N-P ha<sup>-1</sup>), the improved bread wheat cultivar (ET13), the local line (Israel), and two weed management methods (hand weeding and application of 2,4-D), were evaluated on farmers' fields. Highly significant grain yield differences were observed among the treatments. The highest grain yield (2,991 kg ha<sup>-1</sup>) and the greatest benefit were obtained from application of 92-20 kg N-P ha<sup>-1</sup> and 2,4-D herbicide on ET13. Adoption of the improved bread wheat cultivar was highly profitable regardless of fertilizer usage. The effect of fertilizer on grain yield and economic return was much greater than the effect of 2,4-D used alone for weed control.

*Key Words:* Fertilizer, herbicide, 2, 4-D, *Triticum*

### RÉSUMÉ

Le blé (*Triticum* spp) est la principale culture cultivée dans la partie Nord-Ouest de l'Ethiopia. Les contraintes majeures à cette culture dans cette région sont le manque de fertilité du sol, l'utilisation des variétés non améliorées et sensibles, et la dynamique des mauvaises herbes. Un paquet technologique incluant la combinaison de trois doses d'engrais (92-20, 41-20 et 0-0 kg de N-P ha<sup>-1</sup>), la variété améliorée du blé panifiable ET13 et une lignée locale (Israel), ainsi que deux systèmes de contrôle de mauvaises herbes (sarclage manuel et application de l'herbicide 2,4-D), ont été évalués en champs d'agriculteur. Des différences significatives ont été observées entre tous les traitements quant au rendement en grains. Le rendement le plus élevé en grains (2,991 kg/ha) et le plus grand bénéfice étaient obtenus de l'application de 92-20 kg N-P et en utilisant l'herbicide 2,4-D sur la variété ET 13. L'adoption de la variété panifiable de blé était très profitable, indépendamment de l'usage des fertilisants. L'effet des fertilisants sur le rendement en grains et le revenu économique étaient plus grands que l'effet de l'herbicide 2,4-D utilisé seul pour le contrôle de mauvaises herbes.

*Mots Clés:* Fertilisant, herbicide, 2, 4-D, *Triticum*

## INTRODUCTION

Northwestern Ethiopia, in general, and Gojam region, in particular, are among the important wheat growing areas of the country (Aleign, 1988; Amanuel *et al.*, 1991), and have a high potential for the expansion of bread wheat production. Durum wheat (*Triticum turgidum* var. *durum*) has been produced historically in northern Ethiopia, utilising residual moisture on black clay soils, and frequently experiencing moisture stress. In the high altitude zones (>2200 m a.s.l.), a local, tall, awnless bread wheat known as *Israel* (or *Gomadie* or *Zembolel*), is commonly produced by peasant farmers. Minor local varieties such as *Denkezie*, *Tikur Sinde* and *Key Sinde* are also produced. Some farmers have recently started producing introduced, improved bread wheat cultivars such as *Dashen*, *Enkoy* and ET13.

Many peasant families in northwestern Ethiopia suffer from annual food deficits, usually during July-August (Aleign, 1988; Aleign and Regassa, 1989). One of the factors contributing to this seasonal food shortage is the low productivity of local crop varieties under farmers' management practices (Hailu *et al.*, 1989). For instance, local durum and bread wheat varieties frequently yield between 0.4 and 0.8 t ha<sup>-1</sup>. But in on-station bread wheat trials conducted from 1986 to 1987 at the Adet Research Centre, improved wheat cultivars yielded from 3.3 to 4.4 t ha<sup>-1</sup> (Fekadu Fufa, pers. comm.).

Crop production inputs have demonstrated a significant potential to increase farmers' grain yields and net incomes in Ethiopia. The recommended nutrient rate (i.e., the economic optimum) determined for the Adet highland zone is 92-20 kg N-P ha<sup>-1</sup> (Amanuel *et al.*, 1991), although Tanner *et al.* (1993) indicated that use of such a high nutrient level could be unsustainable unless combined with improved weed control practices and disease-resistant cultivars.

Under conditions of moderate to severe weed competition, herbicide application on peasant wheat fields has frequently proved to be profitable (Tanner and Giref, 1991). Furthermore, Lemma *et al.* (1989) reported a significantly positive relationship between grain yield of improved bread wheat cultivars and high level of crop management.

It was hypothesised that the introduction of high yielding bread wheat cultivars, accompanied by a package of improved production technology, could markedly increase crop productivity per hectare. The objective of this study was, therefore, to assess the performance of improved bread wheat production technologies on farmers' fields.

## MATERIALS AND METHODS

The experiment was located at five sites in Goncha Siso Enebssie and Enebssie Sarmidir woredas in eastern Gojam during 1992 and 1993. Ten sites were planted but usable data were obtained from only eight sites. This was mainly due to severe damage by livestock and competition by perennial grass weeds. The distribution of the sites among woredas was based on the perceived potential for bread wheat production. The soils of the experimental sites were primarily reddish-brown Nitisols.

Six treatments were used and are listed in Table 1. Treatments were arranged in a randomised complete block design with two replicates per site. Plot size was 50 m<sup>2</sup> (5 m x 10 m). The 92 kg ha<sup>-1</sup> nitrogen rate was split-applied, half at planting and half top-dressed at the time of weeding or spraying herbicide.

A seed rate of 150 kg ha<sup>-1</sup> was used for all treatments. Land preparation (timing, method and frequency) was carried out by farmers according to their preference and practice. The number of ploughings varied from three to five, including seed covering using the local ox-plough ("maresha"). Similarly, farmers determined the time of sowing and harvesting.

The data collected included grain and straw yield, labour for weeding and harvesting, the cost of fertilizer and labour, and the Adet local market price for bread wheat grain. Farmers' opinions of the technologies were recorded.

Partial budget analysis was carried out according to CIMMYT (1988) methodology, using labour, fertilizer and herbicide costs, and the yield and monetary data for each treatment.

Family labour is the principal labour input in crop production in northwestern Ethiopia (Aleign, 1988; Aleign and Regassa, 1989). The average daily wage has been estimated at 2.7 Ethiopian Birr (EB)/day. This value includes the

food and drinks provided (Regassa and Asmare, unpublished). This value was used as the opportunity cost for labour in the current analysis.

The 1993-94 prices for diammonium phosphate (DAP) and urea were used to derive nutrient prices for the analysis (2.34 EB kg<sup>-1</sup> of N and P<sub>2</sub>O<sub>5</sub> from DAP, and 2.88 EB kg<sup>-1</sup> of N from urea). For sensitivity analysis, the current 16% subsidy on fertilizer was removed.

The official price of 2,4-D in 1993-94 in the study area was 32.3 EB kg<sup>-1</sup>. On the open market, however, 2,4-D occasionally sells for as much as 60 EB kg<sup>-1</sup>, and this price was incorporated in the sensitivity analysis. Farmers usually apply herbicides using borrowed sprayers from the local MOA offices.

The price of wheat grain at the local Adet market was 1.11 EB kg<sup>-1</sup> during the peak months for grain marketing. Sensitivity analysis determined the effects of varying grain price  $\pm 20\%$  relative to the standard market price.

Since donkey hire is rare in the study region, and farmers usually market their grain on church holidays, no opportunity costs for these inputs were included in the analysis.

## RESULTS AND DISCUSSION

**Agronomic analysis.** Grain yields of the six treatments combined over eight trials (site-year combinations) were significantly different among

sites, treatments and their interactions (Table 2). Site yields ranged from 995 to 2,719 kg ha<sup>-1</sup> ( $P < 0.001$ ). Mean yield from the four sites in 1993 (1,532 kg ha<sup>-1</sup>) was markedly lower than that of 1992 (2,108 kg ha<sup>-1</sup>). This could have resulted from excessive rainfall during July and August of 1993 which may have caused grain spoilage.

The two treatments receiving 92-20 kg N-P ha<sup>-1</sup> were the highest yielders across the eight trials (Table 1), and differences among the six treatments were highly significant ( $P \leq 0.001$ ) (Table 2). The significant treatment by site interaction resulted from slight changes in the ranking of treatments across trials. For example, comparing the two top yielding treatments (E-H-C and E-H-H), the former was higher yielding at five sites by an average of 617 kg ha<sup>-1</sup>, while at the remaining three sites, E-H-H was higher than E-H-C by 305 kg ha<sup>-1</sup> on average. Nonetheless, using the mean square for site by treatment interaction as the error term, resulted in a highly significant F value for treatments. The LSD test ( $P \leq 0.05$  level) applied to the six treatments (Table 1) indicated the following significance groupings: E-H-C and E-H-H > E-M-H > L-M-H > L-Z-H; E-Z-H was intermediate between L-M-H and L-Z-H, and did not differ significantly from either.

Orthogonal contrasts were used to partition the treatment sum of squares (SS) into five single degree of freedom comparisons (Table 2). The two contrasts pertaining to the effect of fertilizer,

TABLE 1. Components and grain yield of alternative wheat production technologies included in the verification trials (Adet, 1992-93)

Treatment	Bread wheat variety	Fertilizer (kg N-P ha <sup>-1</sup> )	Weed control method	Grain yield (kg ha <sup>-1</sup> )
E-H-C <sup>a</sup>	ET13	92-20	2,4-D <sup>b</sup>	2991 A <sup>c</sup>
E-H-H	ET13	92-20	HW <sup>d</sup>	2719 A
E-M-H	ET13	41-20	HW	2153 B
L-M-H	Local <sup>e</sup>	41-20	HW	1348 C
E-Z-H	ET13	0-0	HW	995 CD
L-Z-H	Local	0-0	HW	714 D

<sup>a</sup>Coding refers to: ET13 (E) or local (L) variety in first character position; 92-20 (H), 41-20 (M), or 0-0 (Z) in second character; and 2,4-D (C) or hand weeding (H) in third character.

<sup>b</sup>Applied at 1 litre product (720 g a.i. ha<sup>-1</sup>).

<sup>c</sup>LSD at 5% is 439 kg ha<sup>-1</sup>; C.V. = 21.6%.

<sup>d</sup>Farmers' practice: one partial and selective hand weeding.

<sup>e</sup>Referred to as *Israel*, *Gomadie* or *Zembolel* by farmers.

41-20 vs. 0-0 and 92-20 vs. the lower levels, contributed 18.2 and 72.8% of the treatment SS, respectively, and both contrasts were highly significant ( $P < 0.001$ ). This marked effect of fertilizer, and the superiority of the 92-20 level agree with the nutrient recommendation for Adet zone issued by Amanuel *et al.* (1991).

The contrast for variety effect contributed 6.7% of the treatment SS ( $P < 0.001$ ), indicating the superior performance of ET13 relative to Israel. At the two lowest nutrient levels, ET13 out-yielded Israel by 52.7% on average. Israel was observed to be heavily attacked by stripe rust during both seasons.

The interaction of variety by fertilizer contributed only 1.6% of the treatment SS ( $P < 0.10$ ), providing only limited evidence of a greater responsiveness of the improved cultivar to fertilizer. Such a synergism has been reported previously in Ethiopia (Lemma *et al.*, 1989) for semidwarf cultivars, but ET13 possesses a tall phenotype. Presumably, the response of Israel to fertilizer could have been hindered by the detrimental effect of nitrogen in enhancing stripe rust incidence on susceptible genotypes (Tanner *et al.*, 1993).

TABLE 2. Analysis of variance of the grain yield of six bread wheat production technologies (Adet, 1992-93)

Source	d.f.	M.S. <sup>a</sup>	Prob.
Sites (S)	7	3.3	***
Error	8	0.2	***†
Treatments (T)	5	14.1	***†
Variety (V) <sup>b</sup>	1	4.7	***†
Fertilizer (F) <sup>c</sup>	1	12.8	***†
V x F	1	1.0	$P < .10^†$
2,4-D vs. HW <sup>d</sup>	1	0.5	NS <sup>†</sup>
H vs. L <sup>e</sup>	1	51.4	***†
T x S	35	0.3	**
Error	40	0.1	

\*\*, \*\*\* Significant at the 1 and 0.1% levels, respectively.

<sup>a</sup> Values listed must be scaled by  $10^6$ .

<sup>b</sup> ET13 vs. local at 41-20 and 0-0 fertilizer.

<sup>c</sup> 41-20 vs. 0-0 across both varieties.

<sup>d</sup> Hand weeding vs. 2,4-D with 92-20 applied to ET13.

<sup>e</sup> Contrast of 92-20 vs. lower levels.

<sup>†</sup> F values derived by comparison to the significant T x S mean square.

The least significant contrast was the one partitioning the effect of 2,4-D vs. hand weeding on ET13 at the 92-20 nutrient level. This contrast contributed only 0.8% of the treatment SS (NS), indicating that the spray application of 2,4-D did not produce a yield increment compared to the farmers' common practice of one selective and partial hand weeding. Unfortunately, no data on weed densities were recorded in the current study. In general, however, weed control research in Ethiopia has indicated that the use of late-applied 2,4-D seldom raises yields relative to hand weeding, while high efficacy herbicides with an earlier window of application more frequently increase wheat grain yields (Tanner and Giref, 1991).

Straw yields (data not shown) ranged from 1,311 (E-Z-H) to 2,792 (E-H-C) kg ha<sup>-1</sup> and were significantly affected by sites ( $P < 0.01$ ) and treatments ( $P < 0.001$ ). Site by treatment interaction was not significant. Straw yields ranked in the following groupings: E-H-C and E-H-H > E-M-H and L-M-H > E-Z-H and L-Z-H. Fertilizer nutrient levels dramatically increased wheat straw yields ( $P < 0.001$ ), while the effects of variety and weed control method were both not significant.

Harvest indices (HI) (data not shown) ranged from 31.7% (for the local variety in L-Z-H) to 51.2% (for ET13 in E-H-C). HI groupings were ranked as follows: E-H-C, E-H-H and E-M-H > E-Z-H > L-Z-H. L-M-H was intermediate between E-Z-H and L-Z-H, and was not significantly different from both. These results reflect both the inherently low HI of the local bread wheat, *Israel*, and the beneficial effect of enhanced crop nutrition in improving the partitioning of photosynthate to the grain.

**Economic analysis.** Labour data for weeding and harvesting specific treatments are summarised in Table 3. The results suggest that more labour was required for hand weed treatments receiving fertilizer (E-H-H, E-M-H and L-M-H). Labour for harvesting appeared to be approximately proportional to the yield of each technology package. These labour data were utilised in the subsequent partial budget analysis.

In the partial budget analysis conducted using standard prices (Table 4), the net benefit associated with each of the six treatments paralleled their

grain yields. Yield and net benefit increased simultaneously from L-Z-H, the lowest, to E-H-C, the highest yielding treatment. However, total costs did not exactly follow this trend as E-H-H (ET13 + 92-20 + hand weeding) cost more than E-H-C (ET13 + 92-20 + 2,4-D) because the official cost of herbicide was less than the value of the hand weeding labour. Thus, in CIMMYT (1988) terminology, E-H-H was dominated by E-H-C (i.e., E-H-C produced a higher net benefit at a lower cost relative to E-H-H).

Marginal rate of return (MRR) analyses were carried out for the six treatments under varying costs and prices (Table 5). In these economic analyses, it was assumed that farmers require a minimal rate of return of 100%, representing an increase in net return of at least 1 Birr for every 1 Birr invested, to be sufficiently motivated to adopt a new agricultural technology. In most countries, the minimum acceptable rate of return ranges between 50-100% (CIMMYT, 1988).

On the basis of the standard prices, there is an obvious advantage for farmers to replace the local bread wheat with the improved cultivar ET13. The MRRs for varietal substitution were 2,500% without fertilizer (L-Z-H to E-Z-H), and 4,868% with 41-20 kg N-P ha<sup>-1</sup> (L-M-H to E-M-H). The MRR for the transition from E-Z-H to L-M-H was <100%, indicating that there would be little incentive to apply fertilizer to the local bread wheat when ET13 without fertilizer produced close to the same economic return. However, comparing E-Z-H to E-M-H (an MRR of 343%),

one can see that the adoption of 41-20 on ET13 was highly profitable. The next logical transition, to E-H-H (although it was dominated by E-H-C), in which 92-20 kg N-P ha<sup>-1</sup> was applied to ET13, was also profitable with an associated MRR of 272%. This substantiates the zone-specific fertilizer recommendation for bread wheat issued by Amanuel *et al.* (1991). Since the cost of hand weeding exceeded the cost of using 2,4-D, E-H-C dominated E-H-H, and resulted in a MRR of 538% (relative to E-M-H). Thus, the use of 2,4-D on an adequately fertilized stand of ET13 was highly profitable with a total rate of return on marginal costs (relative to the low technology package L-Z-H) of 464%.

Under the first scenario considered in the sensitivity analysis, wheat price was held constant, but the fertilizer subsidy (currently 16%) was removed and 2,4-D was valued at 60 EB/l (+86%) as occasionally encountered on the open market. The only change encountered in this MRR analysis (relative to the analysis with standard prices) was that E-H-H was no longer dominated by E-H-C since herbicidal weed control became more expensive than hand weeding. Nonetheless, E-H-C remained the economically optimal technology package, exhibiting a total rate of return on marginal costs (relative to L-Z-H) of 365%.

Only the rates of return were changed by either decreasing grain price by 20% (scenario 2) or by increasing it by 20% (scenario 3). In both cases, E-H-C remained the economically optimal technology package, exhibiting total rates of return (relative to L-Z-H) of 351 and 577%, respectively.

TABLE 3. Labour requirements for hand-weeding and harvesting the alternative bread wheat production technologies (Adet, 1992-93)

Treatment*	Weeding labour ----- (work-days ha <sup>-1</sup> ) -----	Harvest labour
E-H-C	0	23.9
E-H-H	31.7	19.6
E-M-H	32.8	19.1
L-M-H	28.9	12.7
E-Z-H	20.5	13.7
L-Z-H	20.1	9.6

\* See Table 1 for components of treatments.

**Farmers' assessment.** The 10 host and 14 neighbouring farmers were interviewed individually at crop maturity, about the treatment components. All of the farmers acknowledged the yield increasing effects of fertilizer. In the woredas in which the trials were conducted, farmers rarely apply fertilizer to wheat, preferring to apply available quantities on tef (*Eragrostis tef*). In fact, few of the farmers had been aware of the beneficial effects of fertilizer on wheat yield. When asked about their future intentions regarding fertilizer usage on wheat, the majority expressed an interest, but stated their intent to apply lower levels than 92-20 kg N-P ha<sup>-1</sup>. The following reasons were cited to account for their reluctance:

TABLE 4. Partial budget analysis of the alternative bread wheat production technologies (Adet -1992-93)

	Treatment <sup>d</sup>					
	E-H-C	E-H-H	E-M-H	L-M-H	E-Z-H	L-Z-H
Average yield (kg ha <sup>-1</sup> )	2991	2719	2153	1348	995	714
Adjusted yield <sup>a</sup> (kg ha <sup>-1</sup> )	2692	2447	1938	1213	896	643
Gross field benefit (Birr ha <sup>-1</sup> )	2988.12	2716.17	2151.18	1346.43	994.56	713.73
Fertilizer cost <sup>b</sup> (Birr ha <sup>-1</sup> )	367.20	367.20	218.16	218.16	0.00	0.00
Weeding cost <sup>c</sup> (Birr ha <sup>-1</sup> )	52.28	83.70	83.70	83.70	54.00	54.00
Harvesting cost (Birr ha <sup>-1</sup> )	64.80	54.00	51.30	35.10	37.80	27.00
Total costs that vary (Birr ha <sup>-1</sup> )	484.28	504.90	353.16	336.96	91.80	81.00
Net benefit (Birr ha <sup>-1</sup> )	2503.84	2211.27	1798.02	1009.47	902.76	632.73

<sup>a</sup> Adjusted downwards by 10% to more closely reflect yields under farmers' management, harvesting and threshing.

<sup>b</sup> Including the cost of application.

<sup>c</sup> Including the cost of weeding labour, or herbicide and application costs.

<sup>d</sup> See Table 1 for components of treatments.

TABLE 5. Marginal rate of return (MRR) analysis of the six bread wheat production technologies

Treatment <sup>a</sup>	Scenario			
	Standard	1 <sup>b</sup>	2 <sup>c</sup>	3 <sup>d</sup>
E-H-C	538	3741	411	666
E-H-H	D <sup>e</sup>	222	D	D
E-M-H	4868	4868	3874	5861
L-M-H	43.5	25.8	14.8	72.2
E-Z-H	2500	2500	1980	3020

<sup>a</sup>: See Table 1 for components of treatments.

<sup>b</sup>: Fertilizer subsidy (16%) removed; 2,4-D increased by 86%.

<sup>c</sup>: Grain price decreased by 20% (to 0.89 EB kg<sup>-1</sup>).

<sup>d</sup>: Grain price increased by 20% (to 1.33 EB kg<sup>-1</sup>).

<sup>e</sup>: Marginal cost (of E-H-H) was higher than the next highest ranked treatment for net benefit (i.e., E-H-C), according to CIMMYT (1988) methodology.

- lack of cash;
  - reluctance to apply urea except on black soils (reportedly due to previous extension advice);
  - fear that use of higher rates of fertilizer may burn their crop; and
  - limited and untimely availability of fertilizer.
- All respondents had some experience with using

2,4-D, particularly on tef. All were interested in using 2,4-D on wheat due to constraints of labour availability during the peak period for weeding. However, the farmers mentioned the following limitations to the adoption of this practice: untimely and limited availability of 2,4-D through official outlets; a perception that 2,4-D reduced wheat tillering relative to the usual hand weeding practice; and the price of 2,4-D is high (50-60 EB/l) on the private market.

Concerning varieties, farmers were very interested in replacing the local bread wheat with new cultivars. They ranked ET13 positively for bread and "injera" quality, but considered its quality for local beer ("tella") production to be

low. Some farmers were sceptical about the performance of new cultivars on degraded and unfertilised soils.

### ACKNOWLEDGEMENTS

This research was supported financially by the Institute of Agricultural Research (IAR) of Ethiopia with the collaboration of the wheat agronomy component of the CIMMYT/CIDA East African Cereals Programme. The authors also wish to thank the late Tadesse Kebede for his contribution to the research trials.

### REFERENCES

- Aleign Kefyalew. 1988. *Adet Mixed Farming Zone Diagnostic Survey Report. Report No. 4/88*. Department of Agricultural Economics, IAR, Addis Ababa. 42 pp.
- Aleign Kefyalew and Regassa Ensermu. 1989. *Initial Results of Informal Survey: Bahir Dar Mixed Farming Zone. Working Paper No. 5/89*. Department of Agricultural Economics, IAR, Addis Ababa. 35 pp.
- Amanuel Gorf, Asefa Taa, Tanner, D.G. and Mwangi, W. 1991. *On-Farm Research to Derive Fertilizer Recommendations for Small-Scale Bread Wheat Production: Methodological Issues and Technical Results. Research Report No. 14*. IAR, Addis Ababa, Ethiopia. 37 pp.
- CIMMYT. 1988. *From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition*. CIMMYT, Mexico, D.F. 79 pp.
- Hailu Beyene, Franzel, S. and Mwangi, W. 1989. Constraints to increasing wheat production in Ethiopia's small-holder sector. In: *Sixth Regional Wheat Workshop for Eastern, Central and Southern Africa*. Tanner, D.G., van Ginkel, M. and Mwangi, W. (Eds.), pp. 284-293. CIMMYT, Mexico, D.F.
- Lemma Zewde, Tanner, D.G., Eyasu Elias, Amanuel Gorf, Amsal Tarekegne, Tilahun Geleto, Zewdu Yilma and Hailu Gebre. 1989. The relative importance of yield limiting factors on bread wheat in the Ethiopian highlands. In: *Sixth Regional Wheat Workshop for Eastern, Central and Southern Africa*. Tanner, D.G., van Ginkel, M. and Mwangi, W. (Eds.), pp. 214-223. CIMMYT, Mexico, D.F.
- Tanner, D.G., Amanuel Gorf and Asefa Taa. 1993. Fertilizer effects on sustainability in the wheat-based small-holder farming systems of southeastern Ethiopia. *Field Crops Research* 33: 235-248.
- Tanner, D.G. and Giref Sahile. 1991. Weed control research conducted on wheat in Ethiopia. In: *Wheat Research in Ethiopia: A Historical Perspective*. Hailu Gebre-Mariam, Tanner, D.G. and Mengistu Hulluka (Eds.), pp. 235-276. IAR/CIMMYT, Addis Ababa.

