*Journal of Agricultural Science, Cambridge* (1997), **129**, 43–48. *Printed in the United Kingdom*



# Cowpea yield losses attributed to striga infestations

N. MULEBA*, J. T. OUEDRAOGO† AND J. B. TIGNEGRE†

*International Institute of Tropical Agriculture, Cowpea Agronomy, SAFGRAD, 01 BP 1783, Ouagadougou 01, Burkina Faso*

(*Revised MS received 4 November 1996*)

## SUMMARY

Experiments using cultivars with differing degrees of striga resistance were conducted at two sites at Kamboinse in 1988 and at two locations (Kamboinse and Kouare) in 1989 in the Sudan-Savannah region of Burkina Faso. At each site, striga-free (SFP) and striga-infested plots (SIP) were selected. Two factors, location and genotype, were found to be associated additively with yield losses in soils infested by striga. The location effect was probably due to lower soil fertility in the SIP than the SFP plots under farming conditions. Yield losses in SIP relative to SFP ranged from 3·1%, at the experimental station, to 44·2% under farmers' field conditions. The genotype effect was evident at all locations. Depending on the susceptibility of the cultivars, it varied from 3·1 to 36·5% of the mean yield of SFP with an average of 31·4% in susceptible cultivars. The location effect was evident only at Kouare, where SIP plots were under continuous cultivation without appropriate soil fertility maintenance and/or restoration measures. This amounted to *c*. 19·4% of the mean yield in the SFP. To reduce yield losses in soils infested by striga, it appears to be necessary to grow high yielding, striga-resistant cultivars using agronomic practices which are known to improve soil fertility.

## INTRODUCTION

The parasitic weed, *Striga gesnerioïdes*, infests herbaceous wild plants such as *Indigofera hirsuta*, *Tephrosia pedicellata*, *Convolvulaceae* spp., *Euphorbiaceae* spp. and other host plants (Parker & Reid 1979; Ramaiah *et al*. 1983). It causes severe damage to major crops such as cowpea (*Vigna unguiculata* (L.) Walp.), tobacco (*Nicotiana tabacum* L.) and sweet potato (*Ipomoea batatas* (L.) Lam.) (Musselman 1980). In West and Central Africa, *S. gesnerioïdes* infestations are found in ecosystems which are subject to desertification as defined by Dregne (1983). Woodcutting, overgrazing and frequent bushfires reduce vegetative cover and expose the soil to raindrop impact and the ensuring runoff and erosion.

Cowpea yield losses associated with striga infestation have been reported to range from a few kg/ha to total crop failure (Obilana 1987; Atokple *et al*. 1993). The causes of these losses have not been precisely estimated because natural striga infestation is associated with the physical degradation of the soil and low soil fertility.

Aggarwal & Ouedraogo (1988) estimated that the yield losses due to striga infestation on cowpea crops in Burkina Faso averaged 30% in susceptible cultivars. Their experiment was, however, conducted in striga-free plots, which they artificially infested with striga seeds. The soil in their plots, therefore, may have been unrepresentative of striga-infested soils in West and Central Africa which have undergone chemical and physical changes. Only one source of striga resistance was used in their study. Their estimated yield losses, therefore, may not reflect what can be expected in naturally striga-infested soils.

Several different striga-resistant lines, striga-tolerant selections and striga-susceptible cultivars were therefore studied in paired plots. Each experiment was established both in a striga-infested plot (SIP) and in a striga-free plot (SFP), which were located < 20 m from each other. Research objectives were to estimate the yield losses due to soil degradation and those resulting from direct striga parasitism and to determine the magnitude of yield increase due to striga-resistant or tolerant cultivars. This information is critical not only to reduce yield losses caused by striga infestation, but also to demonstrate the advantage of improved soil fertility.

## MATERIALS AND METHODS

Twelve cowpea cultivars which had been shown to differ in striga resistance were subjected to yield loss

* Present address: OAU-STRC-SAFGRAD, 01 BP 1783, Ouagadougou 01, Burkina Faso.

† Present address: Programme Protéagineux INERA, 01 BP 7192, Ouagadougou 01, Burkina Faso.

Table 1. *Characteristics of cowpea cultivars used to determine yield losses by striga infestation in the Sudan-Savannah zone of Burkina Faso in 1988 and 1989*

| Genotype | Days to maturity | Growth habit | Remarks |
|---|---|---|---|
| Striga-susceptible cultivars | | | |
| KN–1 (Vita-7) | 75 | Spreading | Bred at IITA, Ibadan, Nigeria; commercial cultivar in Burkina Faso |
| TN88–63 | 75 | Spreading | Commercial cultivar in Niger |
| KVx396–18–10 | 75 | Spreading | Widely adapted to semi-arid zones of West and Central Africa; bred by IITA-SAFGRAD, Burkina Faso |
| Striga-tolerant cultivars | | | |
| KVx396–4–2 | 75 | Spreading | Widely adapted to semi-arid zones of West and Central Africa; bred by IITA-SAFGRAD, Burkina Faso |
| KVx396–4–4/2 | 75 | Spreading | |
| KVx396–4–4/4 | 75 | Spreading | |
| Test cultivars | | | |
| KVx396–6–1G | 75 | Spreading | Striga-resistant and adapted to Sahelo–Sudanian zones; bred by IITA-SAFGRAD, Burkina Faso |
| KVx396–8–5G | 75 | Spreading | |
| KVx396–11–6G | 75 | Spreading | |
| Striga-resistant cultivars | | | |
| B301 | 75 | Spreading | Landrace from Botswana |
| KVx61–1 | 75 | Spreading | Bred by IITA-SAFGRAD, Burkina Faso, adapted to the Sahelo–Sudanian zones |
| KVx65–114 | 75 | Spreading | |

evaluation experiments under supplemented striga infestations (Table 1). The cultivars were grouped on the basis of previous evidence into resistant and susceptible cultivars (Aggarwal & Haley 1988; Aggarwal 1991) and into tolerant and test cultivars (Muleba *et al*. 1996). The experiments were conducted at two sites at Kamboinse, 16 km north of Ouagadougou, in 1988 and at two locations, Kamboinse and Kouare, 10 km east of Fada N'Gourma, in 1989, in the Sudan-Savannah region of Burkina Faso. At each site or location, a pair of plots was selected, based on observations from a previous year: one free from striga infestation and the other infested with striga. The paired plots were located < 20 m apart. Except for the SFP at Kamboinse Site 2, which was under fallow in 1987, the other plots at the Kamboinse experimental station had been under improved agronomic practices since the late 1970s or early 1980s. In 1989, the experiment was repeated at Site 1 at Kamboinse. At Kouare, the SFP had been under fallow up to 1988, whereas the SIP had been under traditional cultivation for more than 4 years without the use of improved agronomic practices.

The experimental design was a split-plot design with a single replicate of the two striga treatments at each site. The 12 cultivars were nested within main plots with six replicate blocks of cultivars nested within main plots in 1988 and four replicate blocks of cultivars nested within main plots in 1989. Each cultivar subplot measured 4·5 × 5 m. After ploughing and harrowing the field in preparation for planting, the SIP was supplemented with 1-year-old striga plant materials (seeds and plant debris, at a rate of 10 g/m²) mixed with wet sand, broadcast and ploughed under with a hand hoe to ensure uniform striga infestation. Single superphosphate at 50 kg $P_2O_5$/ha was broadcast in all plots and worked into the soil before sowing. Plots at both sites were sown on the same day in mid-July, the optimum sowing time for cowpea (Muleba *et al*. 1991), after a rainfall > 15 mm. Seeds were sown on flat beds at two seeds per hole and thinned to one plant per hole 2 weeks after sowing. Spacing was 0·75 m between rows and 0·20 m between holes in a row. Rows were earthed up 3 weeks after sowing and ridges were tied every 1·5 m to capture and retain rainwater.

The crop was uniformly sprayed with the insecticide Monocrotophos (12 g a.i./ha) when aphids (*Aphis craccivora* Koch) were observed, Deltamethrine (12 g a.i./ha) at flower bud formation, and a mixture of Deltamethrine (12 g a.i./ha) and Dimethoate (400 a.i./ha) 10 days after flowering, for general insect control. Plots were kept free of weeds by hand hoeing before and by hand weeding after striga emergence. The number of days from sowing to 50% flowering, and to first striga shoot emergence, was recorded. Striga shoot density per unit area was assessed in the two central rows of each plot at cowpea ripening. Grain yield was assessed from the four central rows of each plot, leaving 0·50 m off the end of each row. Pods were harvested as they matured, air-dried to constant weight for 10 days, and threshed.

The yield of each experiment was analysed annually

Table 2. *Striga density as affected by cowpea genotype at two locations, Kamboinse and Kouare, in the Sudan-Savannah region of Burkina Faso in 1988/89*

| | Striga density at: | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Kamboinse Site 1 1988 | | Kamboinse Site 2 1988 | | Kamboinse Site 1 1989 | | Kouare 1989 | |
| Genotype | Shoot/m² | Transf. | Shoot/m² | Transf. | Shoot/m² | Transf. | Shoot/m² | Transf. |
| Susceptible cultivars | | | | | | | | |
| KN–1 | 4·65 | 2·11 | 27·89 | 4·89 | 9·75 | 3·02 | 24·50 | 4·15 |
| TN88–63 | 2·50 | 1·57 | 15·72 | 3·85 | 5·50 | 2·32 | 27·75 | 5·13 |
| KVx396–18–10 | 3·23 | 1·77 | 24·65 | 4·81 | 7·25 | 2·63 | 32·00 | 4·37 |
| Mean | 3·46 | 1·82 | 22·75 | 4·55 | 7·50 | 2·66 | 28·08 | 4·55 |
| Tolerant cultivars | | | | | | | | |
| KVx396–4–2 | 3·45 | 1·84 | 16·13 | 3·61 | 8·50 | 2·79 | 13·50 | 3·25 |
| KVx396–4–4/2 | 2·53 | 1·57 | 20·68 | 4·52 | 8·75 | 2·92 | 9·75 | 2·58 |
| KVx396–4–4/4 | 4·17 | 2·03 | 21·13 | 4·42 | 11·50 | 3·35 | 11·25 | 2·84 |
| Mean | 3·38 | 1·81 | 19·31 | 4·18 | 9·58 | 3·02 | 11·50 | 2·89 |
| S.E. (25 D.F.) | | 0·119* | | 0·616 | | — | | — |
| S.E. (15 D.F.) | | — | | — | | 0·330 | | 1·285 |
| Test cultivars | | | | | | | | |
| KVx396–6–1G | 0·03 | | 0·00 | | 0·00 | | 1·75 | |
| KVx396–8–5G | 0·02 | | 0·00 | | 0·00 | | 2·25 | |
| KVx396–11–6G | 0·02 | | 1·67 | | 0·50 | | 0·00 | |
| Mean | 0·02 | | 0·56 | | 0·17 | | 1·33 | |
| Resistant cultivars | | | | | | | | |
| B301 | 0·00 | | 0·00 | | 0·00 | | 0·50 | |
| KVx61–1 | 0·00 | | 0·00 | | 0·00 | | 0·00 | |
| KVx65–114 | 0·10 | | 0·55 | | 0·00 | | 0·25 | |
| Mean | 0·03 | | 0·18 | | 0·00 | | 0·25 | |

Transf., is the square root transformation of striga density.
The S.E.s are the standard errors of the individual transformed cultivar means.
* Significant evidence of cultivar differences $P < 0{\cdot}05$.

and separately using analysis of variance. Analysis of variance was also carried out with square root transformed striga density data for susceptible and tolerant cultivars at each site separately. Combined analyses of variance were carried out on: (i) yields of all treatments at all three sites in both years at Kamboinse; (ii) yields of all treatments at all sites and locations in both years; and (iii) square root transformed striga count data for tolerant and susceptible cultivars in striga-infested main plots at all sites in both years. These analyses provided information on the main effects and the 2- and 3-factor interaction effects of striga infestation, sites and genotypes (see McIntosh 1983). A mixed model was used, with locations as random effects and cultivars as fixed effects. The significance of the striga infestation × site × genotype interaction effects was tested by using a pooled estimate of within 'main plot error', whereas the significance of striga infestation × genotype and site × genotype interaction effects were tested by using the striga infestation × site × genotype interaction effects as error. The significance of the genotype main effects and the significance of striga infestation main effects were tested, respectively, by using site × genotype and site × striga infestation interaction effects as error.

## RESULTS

### *Striga infestation*

Striga-infested cowpea plants were observed only in SIP. At Kouare in 1989, although statistically insignificant, the second replication was less infested by striga than the other replications; the susceptible cultivar KVx396–18–10, in this replication, was virtually free of striga. As a result, the individual data were somewhat more variable at this location than at other locations. The Kamboinse Site 2 in 1988 was shown, in the combined analysis of variance for all striga-infested sites, to be more heavily infested with striga than any other site in either year. Resistant and test cultivars inhibited striga infestation at all sites (Table 2). However, with the exception of KVx61–1, they were not immune to striga infestation. Susceptible

https://doi.org/10.1017/S0021859697004450 Published online by Cambridge University Press

Table 3. *Seed yield of cowpea as affected by genotype × striga infestation interaction at four sites: two each year in 1988 and 1989, at Kamboinse and Kouare, Burkina Faso, in the Sudan-Savannah zone*

| | Site* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Kamboinse Site 1 1988 | | Kamboinse Site 2 1988 | | Kamboinse Site 1 1989 | | Kouare 1989 | |
| Genotype | SFP | SIP | SFP | SIP | SFP | SIP | SFP | SIP |
| | (kg/ha) | | | | | | | |
| Susceptible cultivars | | | | | | | | |
| KN–1 | 937 | 803 | 984 | 1005 | 1396 | 916 | 1726 | 988 |
| TN88–63 | 1559 | 686 | 1394 | 804 | 1349 | 715 | 1188 | 599 |
| KVx396–18–10 | 1529 | 911 | 1571 | 889 | 1374 | 950 | 1920 | 1110 |
| Mean | 1342 | 800 | 1316 | 899 | 1373 | 860 | 1611 | 899 |
| Tolerant cultivars | | | | | | | | |
| KVx396–4–2 | 1363 | 962 | 1521 | 1166 | 1622 | 1144 | 2281 | 1620 |
| KVx396–4–4/2 | 1320 | 1115 | 1620 | 1121 | 1352 | 1233 | 2259 | 1243 |
| KVx396–4–4/4 | 1305 | 938 | 1588 | 1031 | 1656 | 1064 | 2126 | 1371 |
| Mean | 1329 | 1005 | 1576 | 1106 | 1543 | 1147 | 2222 | 1411 |
| Test cultivars | | | | | | | | |
| KVx396–6–1G | 1217 | 1077 | 1381 | 1171 | 879 | 958 | 933 | 771 |
| KVx396–8–5G | 1013 | 842 | 1148 | 1116 | 1383 | 960 | 1520 | 1093 |
| KVx396–11–6G | 1242 | 1241 | 1432 | 1139 | 935 | 1055 | 1826 | 1210 |
| Mean | 1157 | 1053 | 1320 | 1142 | 1066 | 991 | 1426 | 1025 |
| Resistant cultivars | | | | | | | | |
| B301 | 1087 | 1109 | 1077 | 1167 | 899 | 953 | 1153 | 721 |
| KVx61–1 | 1386 | 956 | 1369 | 1267 | 991 | 1215 | 1809 | 1343 |
| KVx65–114 | 1081 | 1009 | 1327 | 1090 | 1094 | 1226 | 1654 | 1232 |
| Mean | 1185 | 1025 | 1258 | 1175 | 995 | 1131 | 1534 | 1099 |
| S.E. (55 D.F.) | 111·8 | 92·3 | 89·2 | 70·8 | — | — | — | — |
| S.D. (33 D.F.) | — | | — | | 153·6 | 110·0 | 204·7 | 85·0 |

* SFP, striga free plots; SIP, striga infested plots.
The S.E.s are the standard errors of the individual cultivar means.

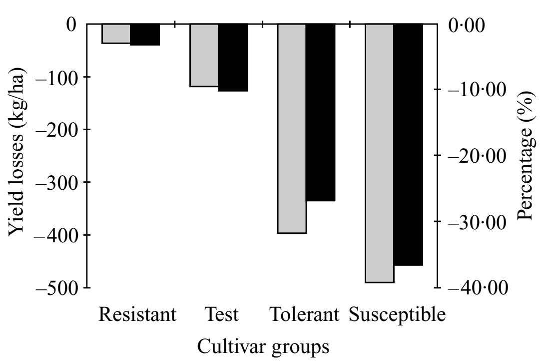


Fig. 1. Average yield losses (kg/ha) (▨) and percentage (%) (■) in cultivars of different striga-resistance characteristics in striga-infested plots relative to striga-free plots at Kamboinse in the Sudan-Savannah region of Burkina Faso in 1988 and 1989.

and tolerant cultivars were equally heavily infested with striga at all sites in both years. Cultivars TN88–63 and KVx396–4–4/2 were, however, exceptions; they were less infested with striga than KN–1 and KVx396–4–4/4 at the Kamboinse sites in 1988.

## *Seed yield*

The yields of all genotypes were lower in SIP than SFP when averaged over sites (Table 3). At the three Kamboinse sites in both years, susceptible and tolerant cultivar yields in SFP were, on average, equal to or significantly higher than test cultivar or resistant cultivar yields in SFP. Tolerant cultivars, however, outyielded susceptible cultivars significantly only at Kamboinse Site 2 in 1988. The average yield difference between resistant and test cultivars was not significant. In contrast, in SIP and at the same sites in both years, tolerant cultivar yields were similar to resistant and test cultivar yields. All these cultivars significantly outyielded susceptible cultivars except for test cultivars at Kamboinse Site 1 in 1989, which did not differ significantly from susceptible cultivars.

Results at Kouare in 1989 (Table 3) were similar to those obtained from all the Kamboinse sites except in

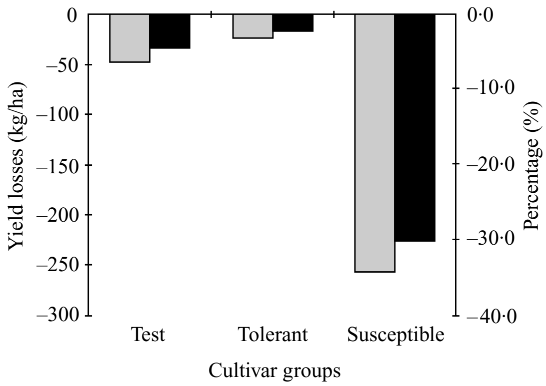


Fig. 2. Average yield losses (kg/ha) (▨) and percentage (%) (■) in test, and striga-tolerant and susceptible cultivar groups relative to the average yield of the striga-resistant cultivar group in striga-infested plots at Kamboinse in the Sudan-Savannah region of Burkina Faso in 1988 and 1989.

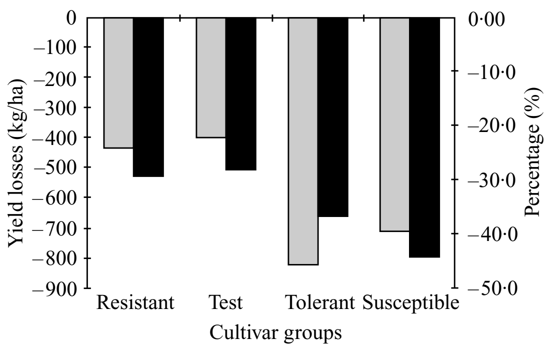


Fig. 3. Average yield losses (kg/ha) (▨) and percentage (%) (■) in cultivar groups of different striga-resistance characteristics in striga-infested plots relative to striga-free plots at Kouare in the Sudan-Savannah region of Burkina Faso in 1989.

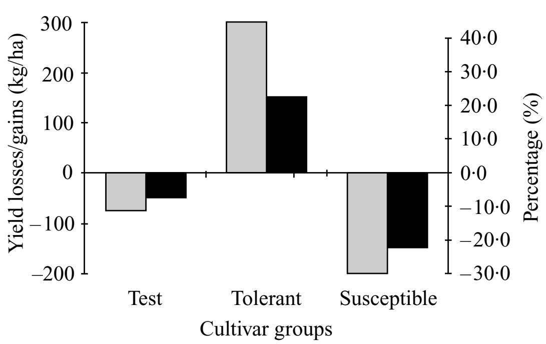


Fig. 4. Average yield losses/gains (kg/ha) (▨) and percentage (%) (■) in test, and striga-tolerant and susceptible cultivar groups relative to the average yield of the striga-resistant cultivar group in striga-infested plots at Kouare in the Sudan-Savannah region of Burkina Faso in 1989.

SIP. Tolerant cultivars in the SIP, on average, outyielded resistant as well as test cultivars. The average yield difference between test and susceptible cultivars was significant only at $P < 0{\cdot}10$ using a 2-tailed *t*-test.

Average yield losses in SIP compared with SFP, based on orthogonal comparisons of data from a combined analysis of variance of yields at all the Kamboinse sites in 1988 and 1989, are presented in Fig. 1. Yield losses were statistically highly significant only for susceptible and tolerant cultivars, and comparable only between resistant and test cultivars and between susceptible and tolerant cultivars. Yield losses were also estimated in relation to the average yield of resistant cultivars in SIP at Kamboinse (Fig. 2). The average yield losses ranged from 24 kg/ha (2·2%) for tolerant cultivars to 257 kg/ha (30·1%) for susceptible cultivars. The difference was, however, highly significant only for susceptible cultivars.

At Kouare in 1989, the combined analysis of variance showed only the striga infestation effect and the genotype effect to be highly significant. Average yield losses in SIP compared with SFP at this location are presented in Fig. 3. Average yield losses varied from 401 kg/ha (28·1%) for test cultivars to 811 kg/ha (36·8%) for tolerant cultivars. Figure 4 compares yields in SIP at Kouare relative to resistant cultivars and shows that yield losses ranged from 74 kg/ha (7·2%) for test cultivars to 200 kg/ha (22·2%) for susceptible cultivars; the differences were highly significant only for susceptible cultivars. In contrast, tolerant cultivars experienced a highly significant yield gain of 312 kg/ha (22·6%) relative to resistant cultivars.

## DISCUSSION

The use of striga-resistant genotypes (resistant and test cultivars) effectively controlled striga infestation and damage on cowpea at all sites. Susceptible and tolerant cultivars sustained comparable, heavy striga infestation at all sites. Both tolerant and susceptible cultivars experienced severe yield losses in SIP compared with SFP. In contrast, the resistant and test cultivars suffered only minor yield losses in SIP compared with SFP. Tolerant cultivars, however, gave comparable or significantly higher yields than the resistant cultivars in SIP at all sites in both years.

Two factors, genotype and site/location, appeared to be additively responsible for yield losses in SIP. The genotype effect was evident at all sites, whereas the site/location effect, reflecting edaphic factors (probably the lower soil fertility in SIP *v.* SFP) was mainly observed at Kouare in 1989 under farmers' field conditions. The average yield loss of striga-resistant genotypes due to striga infestation was

77·5 kg/ha (6·7%) (Fig. 1) at Kamboinse and 418·5 kg/ha (28·3%) (Fig. 3) at Kouare; whereas the average yield loss of the susceptible and tolerant cultivars amounted to 443·5 kg/ha (31·4%) (Fig. 1) at Kamboinse and 761·5 kg/ha (39·7%) (Fig. 3) at Kouare. The average additional yield loss on striga-infested plots at Kouare compared with Kamboinse was 330 kg/ha. However, since SIP at Kouare had been under continuous cultivation, whereas the SFP had been fallow, the extra yield loss of 330 kg/ha or 19·4% of SFP mean yield could have been due to cropping rather than to soil degradation due to striga infestation. There was, therefore, no evidence suggesting that striga affects cowpea yields except by direct parasitism of susceptible cultivars.

An average yield loss of 30% in susceptible cowpea cultivars at Kamboinse, Burkina Faso, was estimated by Aggarwal & Ouedraogo (1988). The authors used an SFP which they infested with striga seed. This loss can be attributed solely to the genotype effect as a result of striga direct parasitism of susceptible cowpea cultivars, and is also consistent with the yield loss of 31·4% observed in this research at the same location. The use of improved agronomic practices (such as fertilizer application, crop rotation and crop residue restitution) at the Kamboinse experimental station is compatible with soil fertility maintenance. To reduce yield losses in soil infested with striga in traditional peasant farming conditions, it therefore appears to be necessary to grow high yielding, striga-resistant cultivars using agronomic practices which are known to improve soil fertility.

A contribution of the International Institute of Tropical Agriculture (PMB 5320, Ibadan, Nigeria) and the Semi-Arid Food Grain Research and Development of OAU-STRC (O1 BP 1783 Ouagadougou 01, Burkina Faso), sponsored by USAID.

The authors express their sincere thanks to T. Bezuneh, International Coordinator of OAU/STRC-SAFGRAD, and all his staff members for help in facilitating the draft and the publication of this paper.

## REFERENCES

AGGARWAL, V. D. (1991). Breeding for *Striga*-tolerance and the development of a field infestation technique. In *Combating Striga in Africa* (Ed. S. K. Kim), pp. 90–95. Ibadan, Nigeria: IITA.

AGGARWAL, V. D. & HALEY, S. D. (1988). Breeding for drought and *Striga* resistance in cowpea. In *Food Grain Production in Semi-arid Africa* (Eds J. M. Menyonga, T. Bezuneh & A. Youdeowei), pp. 307–319. Trowbridge, UK: OAU/STRC-SAFGRAD/Redwood Burn Ltd.

AGGARWAL, V. D. & OUEDRAOGO, J. T. (1988). Estimation of cowpea yield loss from *Striga* infestation. *Tropical Agriculture* (*Trinidad*) **66**, 91–92.

ATOKPLE, I. D. K., SINGH, B. B. & EMECHEBE, A. M. (1993). Independent inheritance of *Striga* and *Alectra* resistance in cowpea genotype B301. *Crop Science* **33**, 714–715.

DREGNE, H. E. (1983). *Desertification of Arid Lands*. London, Paris, New York: Hardwood Academic Publisher.

MCINTOSH, M. S. (1983). Analysis of combined experiments. *Agronomy Journal* **75**, 153–155.

MULEBA, N., MWANKE, M. & DRABO, I. (1991). Use of successional sowing in evaluating cowpea (*Vigna unguiculata*) adaptation to drought in the Sudan savannah zone. 1. Seed yield response. *Journal of Agricultural Science, Cambridge* **116**, 73–81.

MULEBA, N., OUEDRAOGO, J. T. & DRABO, I. (1996). Yield stability in relation to *Striga* resistance in cowpea production in West and Central Africa. *African Crop Science Journal* **4**, 29–40.

MUSSELMAN, L. J. (1980). The biology of *Striga*, *Orobanche*, and other root-parasitic weeds. *Annual Review of Phytopathology* **18**, 463–489.

OBILANA, A. T. (1987). Breeding cowpea for *Striga* resistance. In *Parasitic Weeds in Agriculture* (Ed. L. J. Musselman), pp. 243–253. Boca Raton, Florida: CRC Press.

PARKER, C. & REID, D. C. (1979). Host specificity in *Striga* species – some preliminary observations. In *Proceedings of the Second International Symposium on Parasitic Weeds* (Eds L. J. Musselman, A. D. Worsham & R. E. Eplee), pp. 70–90; Raleigh, NC: North Carolina State University.

RAMAIAH, K. V., PARKER, C., VASUDEVA RAO, M. J. & MUSSELMAN, L. J. (1983). *Striga Identification and Control Handbook*. *ICRISAT Information Bulletin No. 15*. Pantancheru, Andhra Pradesh, India: ICRISAT.