Seed production of native hay clovers in the highlands of eastern Africa

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Abstract

Studies of seed production in some native clovers [*Trifolium steudneri, T. quartinianum, T. rueppellianum* and *T. alexandrinum* (control)] were undertaken at Shola in the Ethiopian highlands (1983) and at Kabete in the central highlands of Kenya (1990). *Trifolium steudneri* and *T. quartinianum* had the highest seed yields on a Vertisol soil at Shola. Seed yields were lower on a volcanic Nitosol soil at Kabete than at Shola, possibly due to the shorter duration of the wet season. At Shola, P fertiliser application significantly ($P < 0.05$) increased seed yields. Highest costs were incurred in hand harvesting and were 82% of total production costs. The yield and seed production costs of African clovers are related to those of other tropical legumes produced in Kenya.

Introduction

Agronomic studies in the Ethiopian highlands have shown that some native clovers have high dry matter production under cutting (Kahurananga and Tsehay 1984). Dry matter accumulation in native clovers has been shown to be responsive to phosphorus (P) (Akundabweni 1984a), a nutrient most limiting to growth of legume crops on the normally K-, Ca-, and Mg-rich volcanic soils present in the highlands of eastern Africa (Murphy 1968; Siderius 1976; Jaetzold and Schmidt 1982). The African clovers have also been reported to have excellent N-fixing ability (Norris and Mannetje 1964), and as such, do not require N fertiliser when grown under local conditions. Furthermore, they have been found to respond to modest P applications on Vertisol soils (Jutzi and Haque 1984). Other advantages reported by Akundabweni (1984b) included: easily harvestable seed from pods which do not shatter; seed sizes that are within the normal ranges for crop plants; and rapid germination of seeds in favourable conditions, comparable with those of already commercialised species such as berseem (*Trifolium alexandrinum*) and white clover (*T. repens*). However, for many of the native clovers, a number of questions remain which warrant further research. Among such issues is the agronomy of seed production, which is vital if new cultivars are to gain rapid farmer acceptance.

Accordingly, a study was conducted in 1983 at Shola (Addis Ababa) on the north-western plateau of the Ethiopian highlands (Site 1) and subsequently, in 1990, at Kabete near Nairobi in the central highlands of Kenya (Site 2). The aims of the study were to: identify the clover giving the highest seed yield; investigate the effects of applied P on seed yield; assess the effects of site on the seed production potential of clovers previously tested and selected at Site 1; and estimate the commercial value of the native clover seed.

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Materials and methods

Site 1

Five clover species were evaluated at Site 1. The effects of P on seed yields of *Trifolium steudneri* (ILCA 9712), *T. quartinianum* (ILCA 6301), *T. decorum* (ILCA 6303), *T. rueppellianum* (ILCA 5791) and an exotic control, *T. alexandrinum* (ILCA 6810), were studied during the long wet season of 1983 in the Ethiopian highlands at Shola (9°00′ N, 38°75′ E; altitude 2300 m). Generally, at this site, the rains fall between June–September (Table 1). Mean annual rainfall is 1122 mm and mean maximum and minimum monthly temperatures are 21.4°C and

9.3°C, respectively. Due to high altitude, night temperatures normally approach the mean minimum over the whole year, while the mean maximum gives rise to a somewhat cool temperate-like climate, especially during daytime.

Seed was sown at a rate of 10 kg/ha in 2 x 4 m plots on a Vertisol (75% clay, <0.002 mm in particle size). Within plots, rows were 40 cm apart. The control was inoculated with the appropriate commercial Rhizobium strain. The plots received P at the rate of 0, 10 or 35 kg/ha as triple superphosphate (46% P). The experimental design was a randomised complete block with 4 replications. Flowering date was recorded as days to first flowering. Seed-heads were hand-harvested at maturity on several occasions and sun-dried before threshing. After threshing, 1000-seed weight was determined at 12% seed moisture content.

Site 2

Trifolium quartinianum and *T. steudneri* were selected from the trial at Site 1 for evaluation during the main season at Kabete, Kenya (1°15′ S, 36°44′ E; altitude 1940 m). *Trifolium tembense* was included as a standard annual native clover used widely in several previous studies.

The mean monthly maximum and minimum temperatures at Kabete were 23°C and 12°C, respectively, with July–August as the coolest period. At this site, temperatures are highest between December–March, but rarely exceed 26°C. The mean annual rainfall is approximately 1000 mm, distributed bimodally. The rainy season is shorter than that in the Ethiopian highlands (Table 1). The soils of the site are humid Nitosols with Oxic Peleustult (Siderius 1976). They are generally deep clays of the Kikuyu red friable loam type formed from tertiary trachytic lava.

Phosphorus was applied at the rate of 94 kg/ha according to Siderius (1976) and Jaetzold and Schmidt (1982). Seeding rates were similar to those used at Site 1. The experimental design was a randomised complete block design with 2 replications and large plot sizes. Plots were 157 m^2 and each plot consisted of 7-m rows with an inter-row spacing of 40 cm.

The experimental area was irrigated once, 3 days after sowing, to ensure good establishment. Regular hand weeding was undertaken. Seed-heads were hand-harvested, commencing with the early maturing *T. steudneri* in the first 2 weeks of August, followed by the later maturing *T. quartinianum* during the last 2 weeks of August. Seed-heads were dried to 12% moisture and threshed and the seed was weighed.

Results

At Shola, Ethiopia, seed yields were 828 and 628 kg/ha for *T. steudneri* and *T. quartinianum*, respectively (Table 2). Seed yields at Kabete were lower (248 and 150 kg/ha, respectively) than at Shola. This was partly due to a shorter rainfall season at Kabete (Table 1).

Trifolium tembense used as a standard performed poorly on the Nitosol soils at Kabete (Table 2) relative to its previous seed yields on the Vertisols at Shola (data not shown). Although *Trifolium steudneri* at Kabete yielded only 30% of the seed previously produced at Shola, it still out-yielded *T. quartinianum* by a 60% margin compared with the Shola margin of 32% between the two clovers. The mean 1000-seed weights of *T. steudneri* and *T. quartinianum* at Shola did not differ significantly (Table 2), suggesting that the differences in seed yield between these species were a function of seed numbers rather than seed size.

Table 1. Rainfall data for Shola (Ethiopia) and Kabete (Kenya) during the main wet season (10-year means).

			Period of main rains			
Shola Kabete	May Mar	Jun Apr	Jul May	Aug Jun	Sep Jul	Oct Aug
			Rainfall (mm)			
Shola	57	109	188	245	162	34
Kabete	78	270	204	31	27	21
			No of wet days			
Shola	12	16	17	24	30	30
Kabete	7	16	13	4	3	4

Table 2. Seed yields of selected African clovers grown at Shola (Ethiopia) and Kabete (Kenya).

Species	SHOLA		KABETE	
	Seed yield	1000-seed weight	Seed yield	50% flowering
	(kg/ha)	(gm)	(kg/ha)	(d)
T. steudneri	828a[1]	1.290a	248a	60
T. quartinianum	628c	1.192a	150b	125
T. tembense			6c	80
T. decorum	532d	0.910d	—	—
T. rueppellianum	264e	0.775d	—	—
T. alexandrinum	53f	—	—	—

[1]Within columns, means followed by different letters differ significantly ($P<0.05$).

Species influence on clover seed yields was significant ($P<0.05$) and of the following order: *T. steudneri* > *T. quartinianum* > *T. decorum* > *T. rueppellianum* > *T. alexandrinum*.

In general, seed yields of clover species at Shola increased ($P<0.05$) in a linear manner with increasing levels of P between 0 and 35 kg/ha P (Figures 1 and 2), although *T. rueppellianum* and *T. quartinianum* failed to respond above 10 kg/ha P.

Table 3 shows the costs of seed production per hectare at Kabete in 1990. Highest costs were incurred in hand harvesting and were 82% of total production costs.

Table 3. Costs incurred in 1990 at Kabete (Kenya) for production of seed of selected African clovers.

Operation	Costs[1]
	(US$/ha)
Land preparation-tractor	40
Irrigation (once only)	10
Seed-bed preparation and hand weeding	120
Fertiliser application	70
Hand harvesting	1177
Threshing, drying and packaging	10
Total	1427

[1]Costs are for cultivation of the clovers studied only. Price differentials between species (see text) are a reflection of costs for harvesting, threshing, drying and packaging, which obviously vary between species depending on seed yield.

Discussion

The results from these 2 sites and from previous research (Akundabweni *et al.* 1991) emphasise that both forage and seed yields of some African clovers are influenced by site and seasonal conditions.

Kabete, because of its shorter rainfall season, may require supplemental irrigation for commercial seed production, especially late in the season. Current cultivars of *Centrosema pubescens*, *Desmodium* or *Stylosanthes* grown in Kenya produce, on average, no more than 300 kg/ha when hand harvested. For commercial seed, yield is low in Kenyan-grown *Medicago sativa*. Comparatively, unless seed production at sites like Kabete can be increased in African clovers to the levels obtained in Ethiopia, seed prices would have to be higher than the current prices of centro or lucerne (alfalfa) and in line with those of stylo and desmodium for profitable seed production.

Trifolium rueppellianum and *T. alexandrinum* at Shola because of the poorer stands relative to the other clovers during that period gave low seed yields. *T. tembense* also grew very poorly at Kabete. Differential site conditions alone do not seem to entirely explain the relatively low yields of *Trifolium rueppellianum* and *T. tembense* and even of *T. quartinianum*. Recent observations from a controlled greenhouse study at Kabete suggest that genotype and environment influence not only dry matter distribution between shoot and root but also the reproductive allocation (L. Akundabweni, unpublished data). That being the case, site of original germplasm collection (Kahurananga and Tsehay 1991), cropping season, amount of precipitation and distribution (Akundabweni *et al.* 1991) plus a number of other factors appear to significantly interact with the genotype to influence its ultimate productivity.

The later flowering time and early drought at Kabete undoubtedly resulted in relatively lower seed yields due to either the abortion of flowers or failure in seed set and/or ripening. By the time the clovers reached 50% flowering, rainfall at

Kabete had declined markedly. Moisture stress at anthesis is known to reduce seed in most crops (Garstel and Kerley 1988). Kahurananga and Tsehay (1991) stressed the important influence of moisture on flowering plus forage and seed yields of the native clovers.

Although responses to P occurred in all species, the highest level of fertiliser could not be justified economically. P application should be reduced to an economic minimum under the conditions at Shola.

If the seed harvested at Kabete were to sell in Kenya at the 1990 price of *Centrosema pubescens* or alfalfa, seed returns would be less than the production costs incurred. However, seed production would be profitable if seed sold for the same price as stylo or desmodium seed. The costs of producing seed could be substantially reduced if cheaper methods of harvesting were available.

In conclusion, early flowering genotypes and/or early planting could ensure higher seed yield from clover, and these combined with a reduction

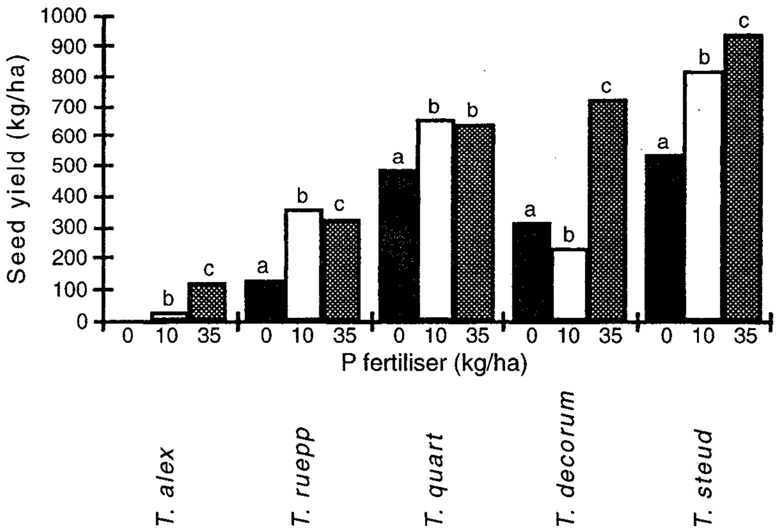

Figure 1. Effect of P fertiliser on seed yields of clover species at Shola, Ethiopia. Within species, columns with different letters are significantly different (P<0.05).

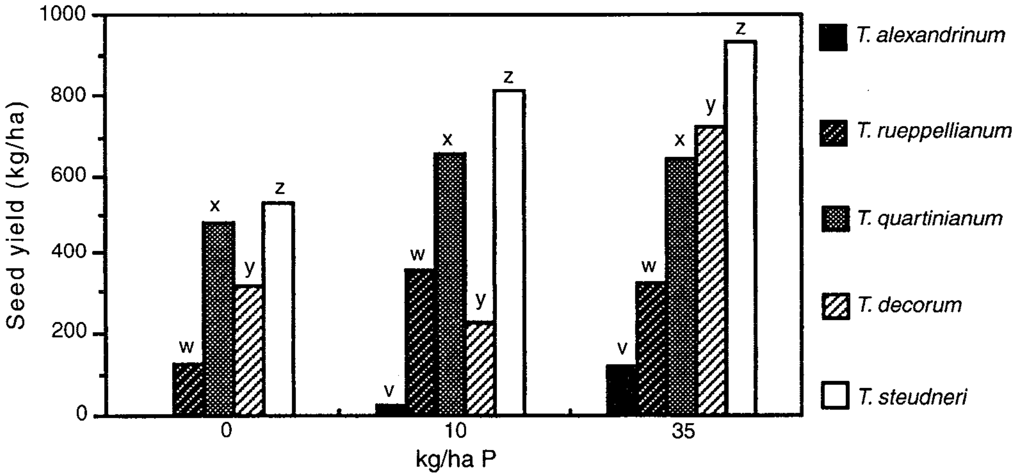

Figure 2. Seed yields of clover species at Shola, Ethiopia, as affected by level of P fertiliser. Within P levels, columns with different letters are significantly different (P<0.05).

in the costs of harvesting would reduce the cost of production to allow a profitable seed-producing industry.

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References

AKUNDABWENI, L. M.S. (1984a) Native clovers of the Ethiopian highlands: The backwood champions. *ILCA Newsletter*, **3**, 5–6.

AKUNDABWENI, L.M.S. (1984b) *Forage potential of some annual native* Trifolium *species in the Ethiopian highlands.* Ph.D. Thesis. South Dakota State University, Brookings, South Dakota, USA.

AKUNDABWENI, L.S., LAZIER, J. and LEMME, G. (1991) Comparative growth of some African clovers grown at different times. *Tropical Grasslands*, **25**, 358–364.

GARSTEL, A.J.G. and KERLEY, J. (1988) *Quality Seed Production.* (International Centre for Agricultural Research in the Dry Areas (ICARDA): Allepo, Syria).

JAETZOLD, R. and SCHMIDT, H. (1982) *Farm Management Hand Book of Kenya.* German Agricultural Team. Volumes I (Western Kenya), II (Central Kenya), and III (Eastern Kenya). (Ministry of Agriculture: Nairobi, Kenya).

JUTZI, S. and HAQUE, I. (1984) Some effects of P and N/P fertilization on three African clovers (*Trifolium tembense, T. rueppellianum* and *T. steudneri*) on a P-deficient Vertisol. *ILCA Newsletter*, **3**, 6–8.

KAHURANANGA, J. and TSEHAY, A. (1984) Preliminary assessment of some Ethiopian *Trifolium* species for hay production. *Tropical Grasslands*, **8**, 215–217.

KAHURANANGA, J. and TSEHAY, A. (1991) Variation in flowering time, dry matter and seed yield among annual *Trifolium* species, Ethiopia. *Tropical Grasslands*, **25**, 20–25.

MURPHY, H.F. (1968) *A Report on the Fertility Status and Other Data on Some Soils of Ethiopia.* (Imperial Ethiopian College of Agriculture and Mechanics: Alemaya, Ethiopia).

NORRIS, D.O and MANNETJE, L. 't. (1964) The symbiotic specialization of African *Trifolium* species in relation to their taxonomy and their agronomic use. *East African Agriculture and Forestry Journal*, **24**, 214–235.

SIDERIUS, W. (1976) Environmental characteristics of Nitosols at Kabete. *Kenya Soil Survey, Miscellaneous Soil Paper No. 10, 1975. National Agricultural Laboratories (NAL), Ministry of Agriculture, Nairobi, Kenya.*

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