Variation in flowering time, dry matter and seed yield among annual *Trifolium* species, Ethiopia

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Abstract

Agronomic evaluation of 96 accessions of 6 native Ethiopian *Trifolium* species was carried out from 1984 to 1986. The earliest and the latest to flower were *T. steudneri* and *T. decorum*, respectively. Early cessation of rain in 1984 caused poor flowering in the late flowering accessions originally collected from higher rainfall (>1300 mm) areas. Accessions of *T. quartinianum* consistently produced high forage yields than other species. Lower yields in 1985 and 1986 than in 1984 were associated with low ground temperatures. The highest average seed yields were produced by *T. steudneri*.

Resumen

Durante 1984 a 1986 se condujeron evaluaciones agronómicas de 96 accesiones de 6 especies Trifolium *nativas de Ethiopía.* T. steudneri *y* T. decorum *fueron las especies más temprana y la más tardía respectivamente. La suspensión temprana de las lluvias en 1984 ocasionó una pobre floración de las accesiones tardías originalmente colectadas en áreas con altas precipitaciones (>1300 mm). Las accesiones de* T. quartinianum *produjeron consistentemente altos rendimientos de forraje. En 1985 y 1986 se obtuvieron menores rendimientos que en 1984, lo cual fue asociado con las bajas temperaturas del suelo.* T. stuedneri *produjo los mayores rendimientos promedio de semilla.*

Introduction

The Ethiopian highlands support the largest livestock population in Africa consisting of 18 million cattle, 25 million sheep and 5 million equines (Jahnke and Asemenew 1983). However livestock production is low because of poor nutrition which usually consists of rough grazing and cereal straw (Jutzi *et al.* 1986). To alleviate the situation, the International Livestock Centre for Africa (ILCA) adopted a strategy based on forage legumes. Legumes would provide high quality feed while at the same time improving soil fertility through biological nitrogen fixation (ILCA 1982).

The introduction of forage legumes is constrained by periodic frosts, extended dry seasons and extensive areas of seasonally water-logged black clay soils (Vertisols) low in pH and available P (Haile 1979). On the other hand, Ethiopia has a large diversity of *Trifolium* species which are adapted to these conditions. There is a total of 28 species out of which 8 are endemic (Thulin 1983). Preliminary assessment showed that some of the annuals had good dry matter (DM) production (Kahurananga and Tsehay 1984). It was therefore decided to evaluate time to flowering, shoot yield and seed yield over several years to take account of climatic variability.

Materials and methods

The trials were conducted at Shola, Addis Ababa, Ethiopia on a less water-logged site than the one used for the preliminary evaluation in 1983 (Kahurananga and Tsehay 1984).

The 1984 trial included 24 accessions of 6 species, of which, *T. decorum* was endemic to Ethiopia. Also another new and unidentified endemic *Trifolium* species (ILCA No. 9452) collected from Metekel, Gojam region, was included. A completely randomised design with 3 replicates was used.

The plots measured 5 m x 2 m with 1 m paths. Planting was on June 17, 1984 at the beginning of the long rains. Triple superphosphate was drilled in rows 20 cm apart at a rate of 40 kg/ha

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P after which scarified seed was planted in the rows at a rate of 10 kg/ha.

All plots were clean weeded. Dates of first flowering were recorded. Harvesting was done at an estimated 50% flowering except for accessions, mostly of the endemic *T. decorum* and *T. tembense* ILCA 10181, which had to be harvested early before reaching full flowering, due to cessation of the rains. Two 1 m x 1 m quadrats were harvested at 2 cm height from each plot. The fresh samples from each plot were bulked, weighed and 100 g sub-samples taken and oven dried at 65 °C for 24 hours to estimate dry matter. The uncut portions of the plots were left to mature and two 50 cm x 50 cm quadrats harvested for estimation of seed yield.

The 1985 trial design and methodology were similar to the previous year. A total of 30 accessions, 6 per each of 5 species, were evaluated. This included one accession from each of 4 species grown in the previous year. There was no common accession for *T. rueppellianum*. The trial was planted on June 19, 1985. The quadrats sampled for yield were 50 cm x 50 cm and the fresh subsamples for dry matter determination were 250 g.

The 1986 trial used a similar design to the previous trials but with a plot size of 3 m x 3 m. A total of 42 accessions, 7 each of 6 species were evaluated. There was a common accession from each of the species grown in the previous year except for *T. steudneri*. An endemic species, *T. bilineatum*, not grown in the previous years was included. Planting was on June 24, 1986. Data was collected as for 1985.

All data for days to first flowering, dry matter and seed yield were subjected to analysis of variance.

Results

Climate

Rainfall and temperature records were obtained from the ILCA weather station in Addis Ababa. Total annual rainfall varied from 963 to 1202 mm with the lowest and highest amounts falling in 1984 and 1986, respectively (Table 1). Average minimum and maximum temperatures were similar for all years, but the ground level temperature reached frost levels during the growing season, June to September, in 1985 and 1986.

Flowering

In 1984, there were significant differences between and within species in days to flowering ($P < 0.001$). The number of days to flowering varied from 54 to 111 days. *T. steudneri, T. rueppellianum* and *T. quartinianum* flowered early, *T. tembense*, except for ILCA 10181, midseason and *T. decorum* and the new *T. sp.* flowered late. The highest variation was exhibited by *T. tembense*. *T. decorum* and *T. rueppellianum* did not show any significant variation within species (Table 2).

Flowering among accessions in 1985 took 72 to 96 days which was mostly midseason except for *T. quartinianum* which was late. The amount of variation between and within species was less pronounced than in the previous year (Table 2).

Flowering in 1986 took 65 to 99 days and was mostly midseason except for *T. decorum* which was late. Levels of variation were similar for all species (Table 2).

Table 1. Rainfall and average temperature at Shola, Addis Ababa, from 1984–1986

	Rainfall			Temperature Maximum			Minimum			Ground level — minimum		
	1984	1985	1986	1984	1985	1986	1984	1985	1986	1984	1985	1986
		(mm)						(°C)				
Jan.	0	29	0	22.8	23.0	23.0	5.8	8.4	6.7	10.0	−5.5	−3.5
Feb.	3	0	44	23.8	23.6	23.3	6.3	8.3	10.6	1.5	−2.5	1.0
Mar.	31	24	71	24.9	24.6	23.5	11.4	10.0	10.6	4.0	−4.0	1.5
Apr.	13	110	217	26.3	22.7	22.3	11.0	11.0	11.8	7.0	−2.0	5.5
May	153	119	51	23.9	23.0	23.7	12.0	11.2	11.6	8.5	−0.5	1.5
Jun.	214	94	226	21.3	22.6	20.9	10.8	10.5	10.8	7.5	−0.5	1.0
Jul.	284	228	168	20.0	19.3	20.4	10.5	10.4	10.9	8.0	0.5	6.5
Aug.	163	280	260	20.8	19.7	20.7	10.6	10.7	10.4	8.5	0.5	2.5
Sep.	100	138	124	20.9	20.6	21.1	10.4	10.5	9.9	6.5	3.5	−2.5
Oct.	0	37	37	22.3	21.4	22.0	8.5	9.4	8.1	4.5	−0.5	−2.0
Nov.	0	0	0	22.6	22.1	22.8	8.2	6.9	7.4	−4.0	−3.5	−3.5
Dec.	3	0	2	22.1	22.0	22.9	7.3	7.1	6.5	1.5	−3.5	−4.0
Total	964	1059	1200									

Table 2. Time of first flowering and forage and seed yields of annual Ethiopian *Trifolium* species grown at Shola, Addis Ababa in 1984, 1985 and 1986

Species	ILCA No.	Trial	First flowering[1]	Forage Yield	Forage Period[2]	Relative yield[3]	Seed yield
			(days)	(kg/ha)	(days)		(kg/ha)
T. decorum	6264	1984	107	5400	124	100	40
"	9435	"	107	5800	124	110	30
"	9437	"	108	4300	122	80	30
"	9447	"	109	7500	123	140	50
"	9458	"	106	4200	123	80	10
"	6264	1985	83	3400	112	100	190
"	6272	"	83	4000	103	120	150
"	7776	"	83	3100	94	90	960
"	9682	"	85	2300	94	70	920
"	9689	"	82	3000	94	90	1020
"	9691	"	73	3000	89	90	1200
"	5729	1986	99	2700	118	120	30
"	6264	"	98	2200	100	100	40
"	6272	"	93	3000	112	140	30
"	7776	"	85	2100	101	9	290
"	8525	"	93	1700	115	80	280
"	10885	"	85	1900	103	90	200
"	10888	"	78	1600	92	75	350
T. quartinianum	6301	1984	66	7800	102	100	870
"	8521	"	71	6200	85	80	1600
"	9378	"	65	5500	80	70	1100
"	9379	"	71	6800	102	90	870
"	6300	1985	86	4100	99	110	730
"	6301	"	92	3700	92	100	800
"	7675	"	96	4200	103	110	1047
"	9428	"	93	4400	104	120	788
"	9968	"	86	1100	99	30	1134
"	10059	"	86	1100	96	30	630
"	6300	1986	90	2800	102	80	170
"	6301	"	97	2300	109	100	210
"	7675	"	98	2000	110	90	300
"	8521	"	80	2600	98	110	840
"	8540	"	96	2500	112	110	220
"	9378	"	74	1300	86	60	170
"	9428	"	97	2600	112	110	320
T. rueppellianum	6218	1984	65	4700	104	90	360
"	6260	"	68	5300	105	100	230
"	6290	"	69	5200	84	100	590
"	9955	"	65	3700	72	70	250
"	5813	1985	83	2300	94	100	400
"	6229	"	85	2400	94	100	740
"	6254	"	84	2100	91	90	450
"	8545	"	83	2600	96	110	500
"	9690	"	82	1000	93	40	140
"	11552	"	96	2500	83	100	740
"	6229	1986	73	1400	89	90	150
"	6260	"	84	1500	100	100	130
"	8233	"	65	1200	80	81	270
"	8545	"	84	1500	100	102	80
"	8768	"	88	1000	70	107	160
"	9369	"	80	1900	130	96	160
"	11552	"	78	1600	110	90	210

Dry matter (DM) yield

Mean DM yield in 1984 varied from 3700 to 7800 kg/ha with the lowest being recorded for *T. rueppellianum* (ILCA 9955) and the highest by *T. quartinianum* (ILCA 6301) respectively. The most significant variation within species ($P < 0.001$) occurred within *T. decorum* whereas *T. tembense* had none (Table 2). There was also significant variation between species.

The DM yields in 1985 were about half of those in 1984. Again *T. quartinianum* had the highest yielding accession, ILCA 6301, and highest mean yield. Variation between and within species was highly significant ($P < 0.001$).

The DM yields in 1986 were even lower than those of the previous year (Table 2). The new entry *T. bilineatum* had the highest producing accession, ILCA 7778. Variation between and

Table 2 continued

Species	ILCA No.	Trial	First flowering[1]	Forage Yield	Forage Period[2]	Relative yield[3]	Seed yield
			(days)	(kg/ha)	(days)		(kg/ha)
T. steudneri	6261	1984	54	5300	100	67	1370
"	9058	"	73	5100	100	83	1100
"	9380	"	70	5700	110	93	1480
"	9720	"	64	7000	130	82	1190
"	9956	"	63	4500	85	73	1450
"	6261	1985	72	1300	40	83	840
"	7631	"	86	3200	100	99	1550
"	7853	"	86	2350	70	93	1240
"	9712	"	88	3300	100	96	1400
"	10111	"	88	1100	30	96	960
"	10139	"	90	2500	80	106	1140
"	7628	1986	81	1100	70	98	620
"	7637	"	90	1200	130	101	340
"	8319	"	74	1100	120	87	430
"	9058	"	80	900	100	95	420
"	9380	"	92	1800	200	92	370
"	9712	"	78	1100	120	94	580
"	9720	"	72	1500	170	85	620
T. tembense	7102	"	66	6100	100	85	790
"	8501	"	66	5000	80	90	380
"	9368	"	69	5800	95	95	360
"	9681	"	68	5600	90	93	700
"	10181	"	108	5700	90	108	70
"	7102	1985	83	2000	100	94	880
"	8509	"	76	2400	120	90	960
"	8541	"	83	2400	120	93	890
"	9697	"	79	2200	110	83	1070
"	9715	"	84	2600	130	94	890
"	10182	"	85	2900	145	98	870
"	7102	1986	75	1700	100	105	350
"	8501	"	84	1600	90	98	240
"	8509	"	75	1600	90	91	360
"	8541	"	95	1400	80	110	90
"	9715	"	85	2200	130	105	140
"	10182	"	77	1400	80	96	330
"	14578	"	67	1400	80	81	440
Trifolium sp.	9452	1984	111	6100	100	124	240
T. bilineatum	7778	1986	89	3100	110	109	258
"	8343	"	75	2300	80	90	466
"	8355	"	75	2000	70	92	698
"	8457	"	77	1800	60	95	296
"	8472	"	84	2400	80	101	183
"	10086	"	95	2900	100	115	331
"	10128	"	74	1700	60	93	403
LSD ($P < 0.05$)		1984	4	930		2	220
		1985	7	1120		5	350
		1986	7	1070		4	150

[1] Days to first flowering. [2] Days to harvest. [3] Yield relative to a common accession in each species in each year.

within species was less pronounced ($P < 0.05$) than in earlier years.

Seed yield

Seed yields in 1984 varied from 12 to 1600 kg/ha (Table 2). Variation between and within species was highly significant ($P < 0.001$). Although the highest producing accession was from *T. quartinianum*, the highest mean species yield was produced by *T. steudneri*. The lowest producing accession and the lowest mean species yield occurred within *T. decorum*.

Seed yield variation in 1985 was similar to that of the previous year. The best species performance was still shown by *T. steudneri* which also had the highest yielding accession. The lowest production still occurred in *T. decorum*.

Seed yields in 1986 were reduced in most cases to less than one third of the 1985 values. The highest yielding accession was within *T. bilineatum* but *T. steudneri* had the highest mean species yield (Table 2).

Discussion

The trial confirmed the agronomic potential of the annual Ethiopian clovers, *Trifolium* species on highland Vertisol soils as reported earlier (Kahurananga and Tsehay 1984). Similar high intraspecific and interspecific variation has also been reported in the highlands at Bekoji and Kulumsa (FNE 1987).

T. quartinianum ILCA 6301 was the most productive accession and has since been adopted as the standard control. However it is important to note that each of the species tested had some productive accessions indicating the versatlity of the group as a whole.

Ethiopian *Trifolium* species used in the trials are adapted to a range of rainfall conditions, from 1165–1676 mm with *T. steudneri* at the lower and *T. decorum* at higher rainfall (Russell-Smith and Fissehaye 1989). Mean rainfall at Shola from 1981–1987 was 1119 mm with 720 mm falling between June and September, the main rain season (Showamare 1988). Rainfall during the rainy season in the study period varied from 737–777 mm which was within the normal range.

Flowering was affected by rainfall and seemed to be related to the rainfall at the site of origin. Early flowering accessions came from lower rainfall areas, midseason ones from medium rainfall areas, including Shola, and late flowering ones from high rainfall areas. Analysis of 1984 data (Table 3) showed a high positive correlation between days to flowering and average rainfall at the site of origin ($r = 0.78$). These results compare well with other observations on *T. tembense* at Shola in which accessions from low rainfall areas flowered early while those from high rainfall areas flowered late (Akundabweni 1984). Similar observations were made in Australia with *Stylosanthes humilis* (Cameron 1967).

The variation in flowering shown by the clovers at Shola, as well as the early flowering of *T. steudneri* and *T. rueppellianum* agree with other results (Akundabweni 1984). In a pot experiment, accessions of *T. steudneri* flowered in 50–76 days and shorter daylength had a positive influence on flower initiation (Weise 1986). This agreed with earlier growth chamber observations in Australia where this species flowered earlier under short daylength (Mannetje and Pritchard 1968).

Forage yield was less sensitive to rainfall than flowering but was still related to rainfall at the site of origin. The results indicate that a minimum of 1000 mm is needed for forage production for most of the species. This is illustrated by the 1984 data for *T. decorum* where accessions from high rainfall areas had good forage production but poor flowering and seed yield. This confirmed results from Debre Zeit with *T. steudneri* in 1983 when total rainfall was 672 mm. Accession ILCA 9058, from a higher rainfall area of 1200 mm, produced 1420 kg/ha DM compared to a local accession ILCA 6261 which produced 3085 kg/ha DM (Tsehay and Kahurananga 1984). In this trial at Shola, the higher forage yields were generally produced by late maturing accessions which were originally collected from higher rainfall areas.

Although rainfall was adequate in 1985 and 1986, DM yields were low. This was most likely due to the low temperatures during the growing season. In 1984 when growth was high, mean absolute minimum ground level temperature between June and September was 7.6 °C while in 1985 and 1986 it was 1 °C and 1.9 °C, respectively. Poor growth of clovers and other legumes at Holetta in 1985 was attributed to low temperatures during the growing season (FNE 1986). It was also shown in other studies that clover growth was faster during the active growing period at Debre Zeit which is lower and

Table 3. Rainfall at the site of origin and days to first flowering of *Trifolium* spp. grown at Shola in 1984

Species	ILCA No.	Mean rainfall at site of origin	Days to first flowering
		(mm)	
T. decorum	6264	1600	107
"	9435	1750	107
"	9437	1700	108
"	9447	1550	109
"	9458	1650	106
T. quartinianum	6301	1200	66
"	8521	1250	71
"	9378	1000	65
"	9379	1250	71
T. rueppellianum	6218	1000	65
"	6260	1200	68
"	6290	1250	69
"	9955	1000	65
Trifolium sp.	9452	1750	111
T. steudneri	6261	860	54
"	9058	1200	73
"	9380	1250	70
"	9270	1200	64
"	9956	1000	63
T. tembense	7102	1050	66
"	8501	1200	66
"	9368	1250	69
"	9681	1350	68
"	10181	1500	108

Linear correlation coefficient between days to first flowering and rainfall at site of origin, $r = 0.78$ ***

warmer than Shola (Akundabweni 1984; Weise 1986).

The high seed production shown by *T. steudneri* and *T. quartinianum* agreed with other observations at Shola and Debre Zeit in which the species produced 800–900 kg/ha seed (Akundabweni 1984; Weise 1986).

Whereas 1000 mm rainfall is necessary for high forage production at least 1300 mm is needed for good flowering and seed production of accessions from high rainfall areas, especially *T. decorum*. Ground temperatures below 7 °C during the growing season retard growth. Thus an elevation of about 2600 m is about the upper limit for good production with the probable exception of some *T. tembense* accessions, collected from elevations above 2500 m.

All the species evaluated in the trials grew well at Shola and did not seem to have any nodulation problem. However, work in Australia showed that African *Trifolium* species are highly specialized in their *Rhizobium* requirements (Norris and Mannetje 1964). As a result they could only be introduced into areas without a natural population of the specific *Rhizobium* species when they are inoculated with the right *Rhizobium*.

Preliminary studies at the Welsh Plant Breeding Institute indicated that there was general cross-inoculation between the different annual Ethiopian *Trifolium* species and different *Rhizobium* isolates. While the level of nodulation varied between *Trifolium* species, *T. quartinianum* nodulated well with most of the *Rhizobium* strains (Myton *et al.* 1988). The results showed that annual Ethiopian clovers were specific more as a group rather than as individual species. This would seem to indicate that the annual Ethiopian species can be introduced to an area where African *Trifolium* species naturally occur. They have been grown successfully at Uyole in the southern highlands of Tanzania where natural populations of some of the African clovers occur. Elsewhere, inoculation with African *Rhizobium* strains would be required.

The variation shown by the Ethiopian *Trifolium* species indicates a wide range of genetic variability. In fact Ethiopia is generally recognized as the centre of distribution of this Genus in tropical Africa (Thulin 1983). The Ethiopian clovers thus offer potential material from which selections can be made to suit different eco-climatic conditions of the African highlands. Further afield, they might be useful in the subtropical areas of Australia. One of the perennial African clovers, *T. semipilosum* is already under commercial utilization there (Jones and Cook 1981).

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