

Effect of seedbed methods and time of harvest on the yield and nutritive value of some forage crops grown on Vertisol at Debre Zeit, Ethiopia

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TEDLA, A., AIRAKSINEN, H. & MOHAMED-SALEEM, M.A. 1992. **Effect of seedbed methods and time of harvest on the yield and nutritive value of some forage crops grown on Vertisol at Debre Zeit, Ethiopia.** Agric. Sci. Finl. 1: 491-497. (International Livestock Centre for Africa (ILCA), P.O. Box 5689, Addis Abeba, Ethiopia.)

The influence of the improved drainage broadbed and furrow (BBF), as opposed to the traditional flat seedbed over the growing season on the dry matter yield and nutritive value of *Avena sativa*, *Vigna unguiculata*, *Lablab purpureus*, *Vicia dasycarpa*, *Trifolium steudneri* and *Sesbania sesban* were studied on Vertisol. Up to 7 t/ha dry matter yield was recorded for *Avena sativa* and *Lablab purpureus* when planted on Vertisols with improved drainage. Dry matter yield of forage crops also increased with advance in stage of maturity or subsequent harvests. On both improved and traditional flat seedbed methods, the chemical analysis of forage crops showed similar declines in crude protein content and *in vitro* dry matter digestibility (IVDMD) levels as the maturity of forage crops progressed.

Key words: Ethiopian highlands, Vertisols, forage legumes, *Avena sativa*

Introduction

Integrated crop-livestock production is a long tradition in the Ethiopian highlands (above 1500 m altitude). Livestock provides draught power for tillage and transport and manure for crops while crop residues serve as important feed resources (GRYSELS 1988).

Vertisols (deep clay soils) in Ethiopia cover about 12 million ha; 7.6 million ha are found in the highlands. Only about 2 million ha of Vertisols are under cultivation in the highlands. The remainder is not cropped because of waterlogging caused by high rainfall amounts (JUTZI 1986).

The traditional flat seedbed method is generally used on Vertisols by farmers. However, it cannot effectively overcome the problem of waterlogging (BERHANU 1985). Research at the International Livestock Centre for Africa (ILCA) on animal traction showed that the development of an appropriate animal drawn implement (broadbed maker) for seedbed-shaping helped to overcome the problems of waterlogging. The broadbed maker forms the seedbed into broadbeds and furrows (BBF) which provides better drainage for cropping.

On Vertisols and other soils in the highlands, native pasture and crop residue are the major feed resources. However, quality and quantity of these

feedstuffs are insufficient to meet livestock requirements (LULSEGED and ALEMU 1984). Delayed harvest of native pasture for hay is also responsible for its low nutritive quality (JUTZI et al. 1987).

In order to alleviate these problems, ILCA's Highland Programme has focused its research on the evaluation of forage crops, especially legumes, for the highlands. In earlier studies, *Avena sativa*, *Vigna unguiculata*, *Lablab purpureus*, *Vicia dasy-carpa*, *Trifolium steudneri* and *Sesbania sesban* have shown potential for the medium altitude (1500-2400 m asl) highlands of Ethiopia (LULSEGED and ALEMU 1984; JUTZI et al. 1987). These forage crops can provide high quality feed either as cut and carry during the rainy season or as hay for dry season feed when seasonal feed shortages become a serious impediment to meeting livestock requirements. These forage crops are high yielding (ABATE 1984) compared with native pastures that have annual yields of only 3-4 t/ha (JUTZI et al. 1987) of dry matter, are poor in quality and result in low livestock performance in the dry season.

The role of forage legumes in increasing animal performance is well documented (SHAW 1961, 1978; TOTHILL 1974). However, the yield and quality of these forage crops are influenced by harvest time and drainage. In this study, field experiments were designed to examine the yield and quality trends of potential forage crops under the traditional and improved seedbed methods on Vertisol at different harvest times during the growing season.

Material and methods

Field experiments were conducted in the Ethiopian highlands, at ILCA's Debre Zeit Research Station (1800 m asl) from 1989 through 1990. The soil of the experimental site is Vertisol, which would normally present drainage problems in the high rainfall season. Rainfall occurs from mid June to mid September (main rainy season) and from February to April (small rainy season). Average annual rainfall

is about 800 mm, with 70% usually falling in the main rainy season.

In the first year of the study, a randomised complete block design experiment with four replicates in a factorial arrangement of two seedbed methods using three forage legumes giving a total of 6 treatments each in a 3.6 × 20 m plot was established.

The flat seedbed represented the traditional system. The broadbed and furrow (BBF) was the improved drainage system intended to allow early planting on Vertisols and the removal of excess water from the seedbed.

In the second year, the experiment was sown as a split plot design. The two seedbed methods were used as main plots (each 18 m × 20 m) and the forage crops (one fodder oat and four legumes) were used as sub plots (each 3.6 m × 20 m plot) with six replicates of each. The forage crops studied and their seed rates are shown in Table 1. At sowing, 100 kg/ha di-ammonium phosphate fertiliser was applied uniformly to all treatments in both years.

Sampling was done using a quadrant frame of 1 m² in each sub plot which was repeated five times to provide yield estimation per net plot of 5 m² for each forage crop. Harvests were done randomly at 6, 12 and 18 weeks after plant emergence in the first year. Harvesting was carried out at 6, 9, 12, 15 and 18 weeks after plant emergence in the second year in order to determine dry matter yield and

Table 1. Forage crops and their seed rate used for the study on Vertisols in the 1989 and 1990 cropping season.

Study year	Forage Species	Seed rate kg/ha
1989	<i>Sesbania sesban</i>	20
	<i>Lablab purpureus</i>	50
	<i>Vigna unguiculata</i>	75
1990	<i>Avena sativa</i>	100
	<i>Lablab purpureus</i>	50
	<i>Vigna unguiculata</i>	75
	<i>Vicia dasycarpa</i>	25
	<i>Trifolium steudneri</i>	13

nutritive value over the growing season. The dry matter data were subjected to analysis of variance (SAS); LSD and SED were used for mean comparisons.

Results

Dry matter yield

Dry matter yields of the three forage crops in the 1989 crop season at different harvest times over the growing season are shown in Table 2.

There was no significant difference in dry matter yield between the flat and BBF seedbed methods at 6 weeks after emergence. However, at 12 and 18 weeks after emergence, there were significant differences in dry matter yield ($P<0.05$) between the forages grown on the two seedbed methods. Among the forage crops, dry matter yield differences were statistically significant at 6 weeks ($P<0.001$), 12 weeks ($P<0.05$) and 18 weeks ($P<0.01$) after plant emergence.

When harvested at 18 weeks, *Lablab purpureus* had the highest dry matter yield, followed by *Vigna unguiculata*. However, the performance of *Vigna*

unguiculata at earlier harvests was the highest of the two forage crops.

The seedbed method by forage crop interaction on dry matter yield was significant at harvests of 6 weeks ($P<0.05$) and 12 weeks ($P<0.05$) after emergence. The interaction effect at 18 weeks after emergence was not significant.

Dry matter yields of the five forage crops in the 1990 cropping season at different harvest times over the growing season are given in Table 3. With the exception of the 18 week harvest time, there were no significant dry matter yield differences between the flat and BBF seedbed methods. There were highly significant differences ($P<0.001$) in dry matter yield among the forage crops at all harvest times. The interaction of seedbed method by forage crop was only significant ($P<0.05$) at 6 weeks after emergence.

From the forage crops evaluated, *Avena sativa* had the highest dry matter yield (7983 kg/ha) followed by *Lablab purpureus* (6292 kg/ha). The lowest yield was recorded for *Vicia dasycarpa* at 18 weeks after emergence.

Table 2. The mean dry matter yields (kg/ha) of three forage crops under the traditional seedbed method (FLAT) and on drained (BBF) Vertisol and harvested at different times during the growing season at Debre Zeit, 1989.

Seedbeds	Forage crop	Time of harvest (week after plant emergence)		
		6	12	18
FLAT	<i>Sesbania sesban</i>	250	1980	2500
	<i>Lablab purpureus</i>	650	4450	6410
	<i>Vigna unguiculata</i>	830	4780	6010
BBF	<i>Sesbania sesban</i>	540	2490	3650
	<i>Lablab purpureus</i>	470	3360	7140
	<i>Vigna unguiculata</i>	1040	4000	5930
	LSD (5%)	150	1230	1320
F-test probability				
	Seedbed method (SM)	NS	$P<0.05$	$P<0.05$
	Forage crops (FC)	$P<0.001$	$P<0.05$	$P<0.01$
	Interaction (SM \times FC)	$P<0.05$	$P<0.05$	NS

Table 3. The mean dry matter yield (kg/ha) of five forage crops under the traditional seedbed method (FLAT) and on drained (BBF) vertisol and harvested at different times of the growing season at Debre Zeit, 1990.

Seedbed method and Forage Crop	Time of harvest (week after plant emergence)				
	6	9	12	15	18
Seedbed method					
FLAT	467	1299	2965	4325	5134
BBF	390	1102	2935	4443	5672
SED	62	180	366	248	182
Forage Crop					
<i>Avena sativa</i>	740	2303	5022	6471	7983
<i>Lablab purpureus</i>	314	1039	2473	4426	6292
<i>Vigna unguiculata</i>	243	664	2033	3377	4202
<i>Vicia dasycarpa</i>	416	1284	2953	3649	3987
<i>Trifolium steudneri</i>	-	712	2269	3998	4552
SED	118	293	33	313	518
F-test probabilities					
Seedbed method	NS	NS	NS	NS	P<0.05
Forage crop	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001
Interaction (SM × FC)	P<0.05	NS	NS	NS	NS

Table 4. The mean * values of the forage crop chemical composition (nutritional status) harvested at different times on Vertisol at Debre Zeit, 1989.

Harvest time (week)	Forage crop	Ash ¹ %	CP ² %	NDF ³ %	ADF ⁴ %	Lignin ⁵ %	ADF-As %
6	<i>Sesbania sesban</i>	11.2	20.3	37.9	28.0	4.8	0.4
	<i>Lablab purpureus</i>	14.7	18.2	36.4	29.6	4.7	2.2
	<i>Vigna unguiculata</i>	22.1	19.2	40.5	29.1	5.1	4.4
12	<i>Sesbania sesban</i>	8.9	12.6	45.6	34.6	6.1	0.4
	<i>Lablab purpureus</i>	13.3	20.7	42.5	35.8	7.0	1.9
	<i>Vigna unguiculata</i>	10.4	11.8	48.1	40.3	6.7	0.7
18	<i>Sesbania sesban</i>	7.8	11.0	48.5	37.2	5.9	-
	<i>Lablab purpureus</i>	9.0	12.3	48.0	39.4	6.9	0.3
	<i>Vigna unguiculata</i>	9.9	14.7	45.9	37.0	6.7	0.7

* Average value taken from FLAT and BBF seedbed methods. 1. Ash (% of dry matter, DM) 2. Crude protein (% DM) 3. Neutral detergent fiber (% DM) 4. Acid detergent fiber (% DM) 5. Lignin (% DM) 6. Acid detergent fibre-Ash (% DM).

Nutritional value of the forage crops

The chemical analysis of the forage crops for the 1989 season, sampled at different harvest times after plant emergence, is presented in Table 4. The chemical analysis of the forage crops in the 1990 season is shown in Table 5. In general, crude protein content and *in vitro* dry matter digestibility levels declined as the forage crops matured.

The nutritional value of the forage crops at each harvest, using the flat and BBF seedbed methods, showed no statistically significant differences.

Table 5. The mean * values of the forage crop chemical composition (nutritional status) harvested at different times on Vertisol at Debre Zeit, 1990.

Harvest time (week)	Forage crop	Ash ¹ %	CP ² %	IVDMD ³ %
6	<i>Avena sativa</i>	15.3	21.9	79.9
	<i>Lablab purpureus</i>	18.4	22.9	76.4
	<i>Vigna unguiculata</i>	20.6	25.1	79.2
	<i>Vicia dasycarpa</i>	32.3	23.7	76.1
	<i>Trifolium steudneri</i>	-	-	-
9	<i>Avena sativa</i>	13.8	13.5	76.0
	<i>Lablab purpureus</i>	17.4	23.8	74.1
	<i>Vigna unguiculata</i>	19.2	25.3	76.8
	<i>Vicia dasycarpa</i>	24.0	23.4	72.1
	<i>Trifolium steudneri</i>	15.5	20.5	73.7
12	<i>Avena sativa</i>	10.8	6.8	67.9
	<i>Lablab purpureus</i>	12.2	20.4	65.9
	<i>Vigna unguiculata</i>	14.7	22.1	73.2
	<i>Vicia dasycarpa</i>	13.4	24.0	68.3
	<i>Trifolium steudneri</i>	15.6	21.6	75.0
15	<i>Avena sativa</i>	9.8	7.3	62.5
	<i>Lablab purpureus</i>	11.5	8.7	63.2
	<i>Vigna unguiculata</i>	12.6	21.7	68.8
	<i>Vicia dasycarpa</i>	13.0	24.1	62.7
	<i>Trifolium steudneri</i>	15.8	21.1	72.0
18	<i>Avena sativa</i>	10.8	6.6	55.3
	<i>Lablab purpureus</i>	11.0	15.4	63.3
	<i>Vigna unguiculata</i>	11.5	16.0	68.6
	<i>Vicia dasycarpa</i>	12.3	18.7	63.7
	<i>Trifolium steudneri</i>	12.1	11.5	61.2

* Average value taken from FLAT and BBF Seedbed methods. 1. Ash (% DM) 2. Crude protein (% DM) 3. *In vitro* dry matter digestibility (% DM).

Thus, the values for the various quality parameters are presented as an average of the two seedbed methods.

Discussion

At Debre Zeit, an overall positive effect of the BBF was observed at the later stage of forage growth for the forage crops tested. This is reflected in the increased dry matter yields of forage crops over the traditional flat seedbed method. However, indi-

vidual forage crop responses to seedbed method differed over the growing season (Table 2). The dry matter yields of *Lablab purpureus* (harvested at 6 and 12 weeks) and *Vigna unguiculata* (harvested at 12 and 18 weeks) appeared to be higher on the flat seedbed than on the BBF. In part, this can be attributed to the low rainfall (range 700-800 mm per annum), the low clay content (49%) of the soil (KAMARA and HAQUE 1987) and the relatively high evaporative demands that cause varied drainage problems on different forage growth.

These results are in contrast with those from higher altitudes (>2400 m asl) where clay content greater than 60% is recorded for Vertisols, rainfall exceeds 1000 mm per annum and temperatures are lower. These effects result in poor drainage on plant growth throughout the growing season (JUTZI 1983). Of the forage crops tested, *Avena sativa*, *Lablab purpureus* and *Vigna unguiculata* produced high dry matter yields (>6 t/ha) in both seasons.

The legumes are of particular importance for their high forage quality (Table 4 and 5). Protein content was high at the earliest harvests but declined gradually as the legume matured. This result was ex-

pected because older plants are more heavily lignified and normally produce poor quality forage.

Conclusion

The performance of these forage legumes in terms of yield and quality suggests they are crops of choice for integration into mixed crop - livestock systems in the highlands. However, further studies are needed on how these forages are combined with food crops in land short systems in order to be used for livestock feed.

It is expected that if these forage legumes are successfully introduced into the highland cereal cropping system, they could have a significant impact on livestock production.

Acknowledgements. The authors wish to express their appreciation to the Government of Switzerland (SDC) and Finnish International Development Agency (FINNIDA) for the support of Vertisol work reported here at ILCA.

The extensive assistance also provided by the Vertisol staff involved in this work especially W/o Nigist Wagaye and W/t Etalem Engeda are acknowledged.

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Manuscript received March 1992

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SELOSTUS

Kylvöalustan muokkaustapojen ja sadonkorjuuaikojen vaikutusten vertailu kasvien satotasoon ja ravintoarvoon Vertisol-savimailla Debre Zeitissa, Etiopiassa

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Tutkimuksessa verrattiin parannetun pellon muokkauksen (kuivatuksen, leveää kohotettua kyntöviilua käyttämällä (BBF)) ja perinteisen tasaisen muokkauksen vaikutuksia *Avena sativa*n, *Vigna unguinatan*, *Lablab purpureumin*, *Vicia dasycarpan*, *Trifolium steudnerin* ja *Sesbania sesbanin* kuiva-aine satotasoihin ja ravintoarvoihin vertisol-savimailla Debre Zeitissa, Etiopiassa. Tutkimus suoritettiin vuosina 1989 ja 1990. Ensimmäisenä vuonna käytettiin satunnaistettujen lohkojen muotoista faktorikoketta (2×3 tasoa). Toisena vuonna käytettiin osaruutukoetta, jossa pääruututasolla olivat muokkausmenetelmät ja osaruututasolla olivat kasvit.

Tarkoituksena oli testata parannetun muokkauksen (BBF) vaikutusta perinteiseen muokkaukseen verrattuna. BBF-

muokkausmenetelmä mahdollistaa aikaisemman kylvön, koska liika vesi valuu pois kylvöalustalta, mikä mahdollisesti lisää satotasoa. Koelohkoilla, joilla oli käytetty BBF muokkausta, *Avena sativa* ja *Lablab purpureum* tuottivat 7 tn kuiva-aine hehtaarisatoja. Myöhäisempi kasvuaste ja korjuuaika lisäsivät myös kuiva-ainesatoja. Kasvien raakavalkuaispitoisuus ja kuiva-aineen *in vitro* sulavuus aleinivat kasvuasteen edetessä eikä muokkaustavoilla ollut vaikutusta saatuihin arvoihin.

Selostettu tutkimus tehtiin Afrikan kansainvälisessä kotieläintutkimuskeskuksessa ILCA:ssa, Etiopiassa. Tutkimusta rahoittivat Sveitsin hallitus ja Suomen Ulkoasiainministeriön Kehitysyhteistyöosasto.