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Evaluation of forage yield potential of *Stylosanthes* species on acid soils of southwestern Ethiopia

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Abstract
In the current study, 100 accessions belonging to four species of the genus Stylosenthes were evaluated for adaptation and preliminary forage yield in an augmented block design at the forage nursery site of the Jimma Agricultural Research Center during the main cropping season of 2018 to 2021 under a rain-fed condition. Data on plant vigor, fresh and dry matter yields were collected and analyzed. The result revealed a significant difference among the genotypes for field plant vigor, fresh and dry matter yields. These results indicated that the test treatments were significantly different from checks. Among the accessions, 11755 scored the highest mean fresh and dry matter yields (t/ha).

Keywords: Stylosenthes species, block, accessions, augmented design

Introduction
Among the complex interacting factors that affect livestock production in Ethiopia, the supply of feeds with high nutritive values comes to the forefront (Mengistu *et al*., 2021) [9]. Natural pasture remains the main source of feed for ruminants in the country. This is being negatively affected by overgrazing and the expansion of crop production (Kebede *et al*., 2017; Abduku, 2020) [5, 1]. Farmers use their own traditional coping mechanisms to overcome the feed shortage problem during the long dry season. Supplementation of poor quality feeds with pulse residue and/or commercial concentrate is one of the common practices undertaken by farmers (Abduku, 2020) [1]. Most of the live weight gained in the wet season is lost in the dry season, resulting in low net annual growth. Herbage growth follows the rainfall pattern and is predominantly made up of low quality grass. Likewise, crude protein content in the herbage is sufficient only during the growing period. This nutritional stress is associated with reproductive wastage, deaths, and prolonged calving intervals in traditionally managed herds (Tolera *et al*., 2012) [13].
The adaptation and establishment of acid-tolerant forage legumes that could serve as sources of quality feed is a practical and sustainable strategy to increase livestock productivity in the southwest and western regions of the country. One of the forage that could be used for this purpose is *Stylosanthes,* which has been identified as a promising protein supplement with considerable potential for crop-livestock production systems in acid-affected soils (Larbie *et al.,* 1992; Mpanza *et al*., 2020) [7, 10]. The genus *Stylosenthes* contains about 30 species, and each species has several accessions. *Stylosanthes* accessions are easily and reliably established from seed in extensive, low-input systems where other legumes such as *Centrosoma* fail (Nada *et al*., 1992) [11]. This is apparently related to good seedling vigor in spite of small seed size. Rehabilitation and improvement of livestock productivity in acid-affected soils is possible with acid-tolerant improved forages. Therefore, there is a need to identify best-bet *Stylosanthes* accessions in the low pH areas of southwest Ethiopia. The objective of the study was to screen and identify the best accessions of *stylosenthes* species for the low pH areas.

Materials and Methods
Description of the study area
The experiment was conducted on-site at the Jimma Agriculture Research Center during the 2018-2021 cropping season. The soil type is Nitosol with a pH of around 4.4.

The average annual rainfall is 1216.7 mm, with the main wet season from June to September. The maximum and minimum temperatures of the study area were 27 °C and 10 °C, respectively. The experimental study is located at 1753m above sea level. The longitude and latitude of the study area are 7°36'N and 36° 50′E, respectively. The study areas practice mixed farming systems of crop-livestock.

Experimental design and planting materials
The *Stylosanthes* accessions used in the study were obtained from the International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia. A total of ninety seven stylosenthes (*Stylosenthes guianensis*, *hamata*, *scabra* and *seabrana)* accessions along with three checks were evaluated in an augmented randomized block design at the onset of the rainy season in a single row. The experimental design consisted of four randomized blocks. The accessions were sown into a cultivated seed bed at a depth of not greater than 1.5 cm. The seeding rates were 4 to 5 kg/ha. One hundred accessions were planted in a single row of 0.5*2m plot size in four blocks. The check accessions were planted in all blocks, but each of the test treatments to be evaluated was planted only once in the experiment. The positions of three checks and ninety seven test treatments in each block were fully randomized and planted in rows. The standard checks were *S. hamata* (75), *S. scabra* (140), and *S. guianensis* (11737). The *S. guianensis* accession was employed as a local check since it has good performance adaptations in southern Ethiopia (Larbi *et al*., 1992) [8]. The augmented design is used when a large number of test treatments are evaluated and there may not be sufficient seeds to replicate each (Federer and Crossa, 2012) [6]. The design is also used in screening new treatments such as genotypes and drugs (Asante and Dixon, 2009; Wandera *et al*., 2014) [2, 14]. The standard check data is used to adjust mean values of test treatments to make them comparable and also provide an estimate of experimental error.

Data collection
Plant vigor, fresh and dry mater yield data were collected during the forage harvesting stage in main cropping season. Fresh biomass yields were determined by harvesting from 1m^2 area of each plot and weighing first at field and then taking 500 g fresh subsample in the laboratory. The subsamples were oven dried for 72hrs at 65 °C temperature from which dry matter yield per hectare was determined. The plots were visited for harvesting based on growth stage of the legume forage components. Harvesting took place only once during the establishment year and two times based on the existing rainfall situation afterwards.

Statistical analysis
The collected data were entered into the Microsoft Excel sheet to create a database and coded appropriately. The observation on standard checks was first subjected to a simple analysis of variance (ANOVA) using a randomized complement block design by R software. This gave information for further analysis with test treatments. Then the analysis of variance was carried out using augmented block design in R software. Fresh biomass, dry matter yield (t/ha) and plant vigor were determined to compare standard checks and test treatment means. Least significant difference (LSD) at 5% level of probability was used for comparison of means among test treatments and standard checks. Comparisons were made between test treatments in different blocks and between test treatments and standard checks.

Results and Discussion
Plant vigor, fresh and dry matter yield differed significantly among check treatments. The result showed that the 11737 accession had the highest plant vigor performance and fresh biomass yield compared to 140 and 75 accessions (Table 1). 75 accession of check treatment was shown to show lower performance in all traits. The overall mean of plant vigor, fresh and dry matter yield of check treatments were 3.4, 28, and 9, respectively. The block effect was not statistically significant among check treatments (Table 1).

Table 1: Mean yield and yield component of check treatments

Accessions	Plant vigor	Fresh biomass t/ha	Dry matter t/ha
11737	4.6a	43.8a	11.7a
140	3.7b	35.1a	13.6a
75	2.1c	5.2b	1.8b
Treatment	***	**	**
Block	Ns	Ns	Ns
Mean	3.4	28.1	9.1
Cv	11.0	29.2	37.0

Means within a column with different superscripts are significantly different at 5% least significant difference (LSD).

The analysis of variance revealed a significant mean sum of squares for the parameters studied (Table 2). The block effect (unadjusted) and treatment effects (adjusted and unadjusted) were significantly different for the plant vigor, fresh and dry matter yields. However, the adjusted block effects were non-significant for all parameters. The mean square due to checks versus test treatments was significant in results of the treatment adjustment analysis for all parameters. In the block adjustment analysis, check versus test treatment effects had the only significant difference for plant vigor. The two remaining parameters were non-significant. These results indicated that there is a significant difference among test treatments, checks, and test treatments versus checks.

Table 2: Analysis of variance of augmented block design for quantitative parameters of accession of stylosenthes species

Source of variation	DF	Vigor city		Fresh biomass (t/ha)		Dry matter yield (t/ha)	
		MS	P value	MS	P value	MS	p value
Block (ignoring treatments)	3	12.4	***	2810.1	***	272.15	**
Treatment(eliminating blocks	99	1.23	**	346.9	*	43.37	.
Check	2	7.15	***	1644.0	**	161.17	**
Treatment v/s check	97	1.1	***	320.2	*	40.94	.
Treatment (ignoring blocks)	99	1.6	**	430.4	*	51.37	*
Test treatment	96	1.4	**	408.5	*	49.61	*
Test v/s check	1	6.67	***	111.7	Ns	0.81	Ns
Block (eliminating treatments)	3	0.02	Ns	53.7	Ns	8.19	Ns
Residual	6	0.146	-	66.2	-	11.86	-

Stylosenthes guianensis and *Stylosenthes seabrana* plant vigor performance was superior to *Stylosenthes hamata* and scabra across blocks. The highest fresh and dry matter yields (t/ha) were recorded from *S.guianensis* and *S. scabra* compared to *S. hamata* and *S. seabrana* in blocks. The lowest plant vigor performance and dry mater yield were recorded from *S. scabra* and *S. hamata*, respectively.

Table 3: Mean yield performance of Stylosenthes species across blocks

Block	Species	Plant vigor	Fresh biomass t/ha	Dry matter yield t/ha
I	*Stylosenthes guainensis*	3.4	35.4	11
II	*Stylosenthes hamata*	2.8	14.4	5.1
II	*Stylosenthes scabra*	2	26.3	10.9
IV	*Stylosenthes seabrana*	3	13.9	5.8

The overall mean of plant vigor, fresh and dry matter yield of the test accessions were 2.7, 23.11, and 8.12, respectively (Table 4). The *S. guianensis* and *S. scabra* accessions that were higher or comparable to the standard checks in terms of fresh biomass yield tons/hectare include 11751, 11755, 11764, 11854, 11875, 16561, 4, 11781, 11781, 9281, 11593, 11607, and 11252. The test treatment accessions that had the highest dry matter yield (t/ha) compared to check treatments were 11755, 11281, 9281, 11256, 11213, 11854, 11591 and 11252 in acidic soil. The current findings demonstrated that 11755, 11764, 11765, 163, 164, 16561, 14257, 15114, and 170 accessions had the highest plant vigor rate compared to other treatments. And the plant vigor of these accessions was comparable with check treatments of 11737 and 140. Accession 11755 and 11765 had the highest plant vigor rate of 4.95, followed by 163, 164, and 16561 with a 4.45 plant vigor rate. Among the identified superior accessions, 11755 scored the highest mean fresh and dry matter yield (t/ha).

In conclusion, a number of Stylosenthes species accessions performed better in terms of plant vigor, fresh and dry matter yield tons per hectare in acidic environments. As a result, better performing Stylosenthes species accessions in acidic environments could be advanced for further evaluation across locations and years to come up with best yielding acid tolerant candidate variety for release in Southwestern Ethiopia.

Table 4: Adjusted mean values for agronomic characteristics of stylosenthes species accessions from augmented design block analysis

Accessions	Block	Adjusted Means		
		Vigor of seedling	Fresh biomass t/ha	Dry matter t/ha
1	I	0.95	1.29	0.69
11722	I	2.95	31.47	9.34
11748	I	2.95	26.14	7.9
11751	I	2.95	61.57	14.8
11752	I	1.95	-	-
11755	I	4.95	120.57	32.4
11761	I	3.95	39.92	11.26
11764	I	4.25	48.57	14.67
11765	I	4.95	40.17	9.8
11772	I	3.95	34.57	7.16
11777	I	3.95	31.77	9.9
11781	I	3.95	48.37	13.39
11812	I	1.95	46.57	14.2
11826	I	1.95	9.87	3.3
11827	I	1.95	13.62	3.8
11849	I	2.95	17.37	5.8
11854	I	3.95	74.57	17.85
11871	I	3.95	49.32	13.95
11875	I	3.95	51.57	16.22
11889	I	1.95	45.57	2.56
11890	I	3.95	45.57	2.56
12453	I	1.95	21.27	7.3
15557	I	3.95	25.55	7.8
163	I	4.45	9.68	3.1
164	I	4.45	25.09	6.67
16561	I	4.45	49.42	12.76
2	I	2.95	21.99	5.99
4	I	3.95	49.57	12.71
573	I	3.95	10.12	2.9
6995	I	2.95	47.20	13.5
7284	I	2.95	6.02	2.39
7286	I	2.45	15.73	4.89
73	I	2.45	-	-
11003	II	2.95	27.06	10.24
167	II	2.95	25.25	0.5

11636	II	2.95	29.49	10.68
14213	II	3.95	44.62	18.28
14216	II	2.95	19.31	5.6
14218	II	3.95	25.54	8.86
14221	II	2.95	2.74	1.1
14233	II	2.95	6.68	2.5
14237	II	2.95	4.09	1.6
14241	II	3.45	11.10	5.1
14242	II	2.95	-	-
14244	II	3.45	8.67	2.9
14271	II	2.95	11.09	4.18
14278	II	2.95	3.12	1.24
14280	II	3.45	6.7	2.4
14300	II	3.45	7.21	3.5
15804	II	3.45	8.44	2.99
15805	II	2.95	4.55	1.59
15811	II	2.95	4.57	1.56
15857	II	2.95	13.59	5.26
15871	II	2.95	4.16	1.5
15874	II	2.95	22.06	7.73
15876	II	2.95	7.80	2.67
15879	II	2.95	10.02	3.78
15881	II	2.95	7.54	2.91
15894	II	0.45	5.32	2.18
15901	II	0.45	7.7	3.34
15903	II	0.95	5.26	2.08
15908	II	1.95	19.39	7.45
15944	II	0.45	9.21	3.93
15958	II	0.95	6.12	2.71
12555	III	1.62	30.64	13.8
14257	III	4.12	28.24	11.21
6854	III	2.12	21.41	8.08
11252	III	0.62	39.58	16.6
11255	III	0.62	21.01	9.17
11256	III	0.62	43.48	18.63
11281	III	0.62	41.76	20.36
11591	III	0.62	40.28	17.45
11593	III	0.62	36.7	14.52
11595	III	0.62	6.39	2.17
11602	III	1.62	24.51	10.03
11604	III	1.62	29.53	13.17
11607	III	1.62	36.14	14.72
11625	III	1.62	21.15	7.27
15113	III	1.62	-	-
15114	III	4.12	27.85	11.28
15445	III	1.62	33.63	13.38
15446	III	1.62	29.88	10.18
15780	III	1.62	25.85	10.55
15784	III	3.12	30.85	11.82
15785	III	3.12	24.78	11.00
15791	III	3.12	-	-
15795	III	3.12	-	-
15796	III	2.12	7.93	2.8
441	III	3.12	25.78	9.59
9262	III	2.12	35.96	14.58
9268	III	1.62	0	-
9281	III	2.12	42.72	19.3
170	III	4.125	-	-
11247	III	0.62	22.47	9.35
15561	IV	2.95	20.45	8.2
15768	IV	2.95	10.52	4.3
15793	IV	2.95	36.58	15.88
Over all mean	-	2.7	23.11	8.12
CV	-	13.7	32.36	39.01

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