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Forage Yield Potential and Adaptation Performance of Alfalfa Genotypes in Acidic Soil Condition of Southwestern Ethiopia

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ABSTRACT

Background: The adaptability and forage yields of some alfalfa varieties are very low compared to the other varieties. Thus, this experiment was conducted to evaluate the adaptability, forage yield potential and farmers' preference of seven alfalfa genotypes across two agro-ecological conditions of Chena and Gimbo districts, Southwestern Ethiopia in the year 2019 and 2020.

Methods: Seven varieties of alfalfa forage including Magna 788, Magna 801, FL-L77, Hunter river, FG9-09, FG10-09 and Pioneer 1995 were used as experimental treatments. The genotype was arranged using an RCBD with three replications. All the relevant data were collected and then subjected to SAS software. To assess the adaptability and productivity potential of the selected varieties, all necessary data were recorded.

Result: The effect of varieties on adaptation performance and yield potential showed significant differences ($P \leq 0.05$) for all parameters except the date of emergence at both locations. Dry matter yield, biomass yield, leaf weight and stem weight were significantly ($P \leq 0.01$) affected among all varieties of alfalfa. Therefore, all varieties of Alfalfa were found to be adaptable and performed well for most growth parameters and yield components except seed production under the conditions of Gimbo and Chena agroecology.

Key words: Adaptability, Alfalfa, Biomass yield, Farmers' perception, Yield potential.

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is one of the most important forage crops in the world because of its high nutritive quality, yield, good palatability, and adaptation to various climatic and and soil conditions (Li *et al.* 2007; Wenxu *et al.* 2019). Hence, the production of alfalfa plays a vital role in enhancing the livestock production and productivity all over the world. In Africa, Ethiopia holds the largest livestock population, estimated at 65 million heads of cattle, 39 million sheep, 50 million goats, 7.7 million camels, 48.9 million chickens, 2.1 million horses 8.9 million donkeys (CSA, 2020). Its contribution to food, nutritional security, and the overall economy of the country is relatively immense. About 80-83% of the people are employed in agriculture, especially farming. The sector contributes more than 15% of total GDP and about 47.7% of agricultural GDP (IGAD, 2011). However, the contribution of the sub-sector in the country's economy remains below its potential due to the low productivity of animals. Low productivity of animals stems from poor feed resources available to all classes of animals that leads to underperformance of the sub-sector. As ARARI (2019) reported, most of the animals do not get their maintenance requirements from grazing due to its poor quantity and deficiency in most nutrients particularly in protein.

The improved forages at the farmers' level have remained very low due to the shortage of forage seed, the reluctance of most smallholder farmers and the lack of well-organized extension services (Alemayehu and Getnet, 2012). Those improved forages with high productivity, better nutritive value and high palatability could play an important role in both enhancing livestock production and improving soil fertility, and preventing soil erosion. Moreover, adding alfalfa hay to livestock feed can significantly promote the growth and development of livestock and poultry, especially improving the milk yield and quality of dairy cows.

Due to the aforementioned importance, sometimes alfalfa is called the 'Queen of forages' due to its wide adaptation, high yield, better quality, and persistency. This forage widely adapts to different climatic conditions, has good biological nitrogen fixation capacity, and produces high biomass yield with the best nutritive value that supports higher productive animals (Annicchiarico *et al.* 2015). There are numerous factors affecting the forage yield and its components and seed yield, such as varieties, climatic conditions, soil conditions and cultivation management. Thus, it is the best alternative to meet our need for livestock feed in the present land scarcity and degradation as this forage provides better biomass yield and nutritive value within small plots of land. Therefore, it is very important to test adaptability, forage yield potential, and to assess farmer

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perception on those improved forage varieties by selecting widely adopt seven alfalfa varieties in humid acidic soil conditions of southwestern Ethiopia.

MATERIALS AND METHODS

The experiments were conducted over two locations on the Farmer Training Center (FTC) of Chena and Gimbo district of southwest Ethiopia in the year 2019-2020. One of the experimental sites, Chena district located at 7°21′69″ latitude north and 36°23′32″ longitude east. The other study site was Gimbo that located at 07°00′-7°25′N latitude and 35°55′-36°37′E longitude and an elevation of 800-1800 meters above sea level with the exact altitude of the experimental site at 1450 meters above sea level (KZFLD, 2019).

Site selection and land preparation

Forage sites were selected purposively based on proximity to irrigation water sources, sunshine such as shade-free area, which is basic during the later age of production stage, and other factors. The experimental site was held on the farmer-training center (FTC) of each district. During site selection, agroecology is the main considerable factor; *i.e.* the one site was low land and the other highland. Land preparation was done according to the farmers' activities. Seed preparation and sowing procedure: Seven released varieties of alfalfa; Magna 788, Magna 801, FLL 77, Hunter River, FG9-09, FG10-09, and Pioneer 1995 were used from Holleta Agricultural Research Center and Debrezeit Agricultural Research Center. Germination tests were done in the laboratory to ensure the germination rate of seed in the controlled environment. The recommendation of Jayasena *et al.* (2016), for planting depth for alfalfa *i.e.* 0.6 to 1.2 cm was used. The land was ploughed three times during the short rainy season (March-May) using manually.

Experimental design and treatments

The experiment was laid out by using RCBD with three replications. A total of 78 plots for agronomic and farmers' evaluation within different agro-ecological conditions were used. For all alfalfa treatments, a plot size of 3 m×2 m (6 m^2), spacing of 20 cm between rows (a total of 8 rows and the middle 6 rows used for data collection), 50 cm between plots, and 1m between blocks were uniformly adopted along with other recommended cultural practices. The recommended seed rate of 10 kg/ha and fertilizer rate of 100 kg/ha DAP were used (MoANR 2016).

Methods of data collection

In this experiment, plant-based data and soil data were collected. An initial soil sample was randomly collected from the experimental field in a zigzag pattern at the depth of 20 cm using an auger before forage sowing (Wilding, 1985). Soil samples were analyzed in the Jimma Soil laboratory. All plant-based data were collected. From all the plots harvested, a minimum of 500-gram forage samples were taken and oven-dried at 65°C for 72 hours until a constant weight was obtained for dry matter content estimation. After drying, the samples were re-weighed for estimation of dry matter yield. Based on the whole dry matter content, leaf and stem percentage were estimated by separating the leaves from the stems and weighing each component.

Phonological and growth data

Days to emergence

were recorded as the number of days from the date of sowing to the time when the majority (90%) of the planted seeds have emerged just above the ground.

Stand height

was measured as the height of all alfalfa genotypes in centimeters from the base of the main stem to the tip of the panicle/flower and recorded as the total of ten randomly selected forages at 50% flowering from each plot.

Days to forage harvest

were recorded from planting date to the date when alfalfa plants reached the 50% flowering stage.

Days to 90% physiological maturity

were recorded as the number of days from the date of sowing to the date when 90% of the plants showed yellowing of leaves and pods and seed hardening in the pods.

Yield and yield-related parameters

Herbage biomass (t/ha)

Adjacent rows from the center of the plots were harvested at 50% flowering stage of alfalfa, from 1m × 1m ($1m^2$) area by excluding the border rows from each side. The fresh weight was recorded in the field using a weighing balance.

Dry matter yield (t/ha)

The fresh subsample of 300 grams was taken from each treatment and dried at 65°C for 72 hours in an oven for dry matter yield determination.

Farmer preference

Based on the information gained from Development Agents (DA's) and the results of the reconnaissance survey, the selection of target smallholder farmers was carried out. A total of 120 farmers were taken for the survey 60 from each site; in which those farmers are selected based on their interests to be included in the study activities, engagement in livestock production, previous experience on improved forage production and having a potential role to share findings to other smallholders. The development agent keeps records, arranges and encourages a visit to the selected farmers' and helps researchers in arranging visits and field days to follow up the trial.

Data analysis

All measured parameters were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of SAS version 9.4. The LSD was used to determine the statistical significances between treatment means at a 5% level of significance (SAS, 2016). The

F-test for homogeneity of variance carried and its value was computed as the ratio of the two-error mean square the larger error mean square in the nominator and the smaller mean square in the denominator (Gomez and Gomez, 1984). The statistical model used for analyzing the combined effect of agro-ecology and forage varieties on the response variable was.

$$Yij= \mu ij + \alpha i + \beta j + \alpha i*\beta j + eij$$

Where:

Yij= The observed response of forage varieties (i^{th}) and agro-ecology (j^{th}) effect on adaptability. μ= Overall mean, ∝i= the effect of i^{th} treatment (forage varieties), βj = The effect of j^{th} block/replication (agro-ecology), ∝i*βj = Forage variety and agro-ecology interaction effect, eij= Random error

RESULTS AND DISCUSSION

Soil Physical and Chemical Properties

The result of soil physical and chemical properties was presented below in Table 1 and Table 2.

Phenological parameters

Days of 90% emergence

Different varieties of Alfalfa were analyzed on the days of emergence over two locations. The results obtained on days to 90% emergence revealed that the differences between the tested genotype were not significant (Table 3). A similar finding was reported by Hidosa (2015). Even though there is no significant difference in the day of emergence, the mean days of the emergence of alfalfa varieties were longer (9.04 days) at Chena and shorter (7.71 days) at Gimbo. The differences in days to emergence between the two locations were due to the difference in altitude, humidity, and temperature that affect the general physiology of those forages. This may be attributed to the growing nature of some legume genotypes or may be related to the hardy seed coat of different alfalfa seeds.

Forage harvesting date (50% flowering)

Analysis of variance revealed that days to forage harvest for different varieties of alfalfa showed significant (P<0.01) difference at both locations (Table 3). In Chena, the highest and lowest mean days of harvesting were 121 days for pioneer 1995 and 112.6 days for Hunter river respectively. The recorded longest and shortest length of days for alfalfa harvest in the Gimbo site was 102.3 days for *pioneer 1995* and 90.33 for *Hunter river* respectively (Table 3). In Gimbo site forage harvests were early than that of Chena and this may due to the warmer climatic condition of the area which encourages the physiological maturity of the crop. Moreover, in the Chena site, the late-maturing may be due to high and extended rainfall during the cropping seasons that encourage vegetative growth and delayed forage harvesting stages. On average, about 15 to 20 more days were required to harvest forage at Chena in comparison to Gimbo. This indicates the different responses of the tested genotype for these important agronomic traits at both locations.

Growth parameters

Stand height at harvest

The present study showed that there was a significant difference (P<0.001) among the seven varieties of alfalfa at

Table 1: Pre-planting soil analysis results (Soil physical and chemical properties) of Gimbo site.

Parameters	Value	Rating	Remark	References
Soil PH	5.14	Strong acidic	H	FAO (2000)
Organic matter content (%)	3.9%	Medium	S	Sahlemedhin (1999)
Organic carbon (%)	2.3%	Medium	S	Roy *et al.* (2006)
Total nitrogen (%)	0.55%	Low	D	Havlin*et al.* (1999)
Available phosphorus (mg/kg)	3.89	Medium	D	Olsen *et al.* (1954)
Available potassium (mg/kg)	3.87	Low	D	Havlin *et al.* (1999)
Cation exchange capacity (cmol/kg)	12.11	Low	D	Sahlemedhin (2000)
Soil texture	Clay 53%, Sand 22%,Silt 25%	Clay Loam		

Table 2: Pre-planting soil analysis results (Soil physiochemical properties) of the Chena site.

Parameters	Value	Rating	Remark	References
Soil PH	5.9	MA	High	FAO (2000)
OMC (%)	6.1%	H	Excessive	Sahlemedhin (1999)
OC (%)	2.9%	M	Sufficient	Roy *et al.* (2006)
TN (%)	0.52%	L	Deficient	Havlin *et al.* (1999)
AP (mg/kg)	5.84	L	Deficient	Olsen *et al.* (1954)
AK (mg/kg)	4.72	L	Deficient	Havlin *et al.* (1999)
CEC (cmol/kg)	16.12	L	Deficient	Sahlemedhin (2000)
Soil texture	Clay 69%, Sand 16%, Silt 15%	Clay		

Table 3: Mean value for the date of emergence, forage harvesting date, and the number of branches per plant of the seven alfalfa varieties tested combined over the location in the year 2019/2020.

Species	DE (days)		HD (50% blooming)		SH (cm)	
	Gimbo	Chena	Gimbo	Chena	Gimbo	Gimbo
Hunter river	7.1	9.11	90.33[d]	112.66[d]	59.66[a]	64.11[a]
FG10-09	7.66	9.33	95.66[bdc]	117.00[bc]	45.66[c]	45.33[cd]
FG9-09	7.64	9.33	101.33[a]	120.5a	51.33[bc]	44.66[d]
Magna 801	7.33	9.43	95[dc]	120.33[ba]	52.66[b]	47.66[cd]
FL-L77	8.33	8.66	101[ba]	120[ba]	49.66[bc]	50.33[cb]
Magna 788	7.66	8.34	98.33[bac]	115.66[dc]	52.66[b]	54.66[b]
Pioneer 1995	8.33	9.33	102.33[a]	121[a]	53.33[ba]	47.66[cd]
Mean	7.71	9.04	97.7	118.23	52.14	50.61
CV (%)	6.63	6.06	3.21	1.84	7.37	6.22
LSD (0.05)	0.91	0.97	5.59	3.88	6.84	5.6

DE: Date of emergency HD: Harvest date; SH: Stand height.

Table 4: Mean value of some growth parameters and the yield-related component of the seven alfalfa varieties tested combined over the location in the year 2019/2020.

Species	LY (t/ha)		StY (t/ha)		DMY (t/ha)		BMY (t/ha)	
	Gimbo	Chena	Gimbo	Chena	Gimbo	Chena	Gimbo	Chena
Hunter river	1.26[ba]	2.13[a]	2.13[a]	3.26[a]	3.4[ba]	5.4[a]	14.13[a]	18.56
FG10-09	1.5[a]	1.66[b]	2.13[a]	2.56[cb]	3.63[a]	3.8[c]	10.83[bc]	15.76
FG9-09	1.43[a]	1.63[b]	2.15[a]	2.8[b]	3.6[ba]	4.43[b]	13.5[3a]	16.93
Magna 801	1.1[b]	1.4[b]	1.5[bc]	2.36[cd]	2.7[c]	3.7[c]	9.8[c]	15.2
FL-L77	1.23[ba]	1.7[b]	1.83[ba]	2.23[d]	2.96[bc]	3.9[cb]	13.13[ba]	16.46
Magna 788	1.03[b]	1.50[b]	1.12[a]	2.6[cb]	2.43[c]	4.2[cb]	9.5[c]	16.33
Pioneer 1995	1.1[b]	1.53[b]	1.53[bc]	2.33[cd]	2.63[c]	3.8[c]	9.9[c]	14.66
Mean	1.23	1.65	1.8	2.59	3.04	4.19	11.54	16.41
CV (%)	12.53	11.04	12.1	6.86	12.07	7.79	12.73	8.94
LSD (0.05)	0.29	0.32	0.42	0.31	0.65	0.58	2.61	2.62

LY: Leaf yield; StY: Stem yield; DMY: Dry matter yield BMY: Biomass yield.

forage harvesting stages (Table 4). Among all varieties, *Hunter river* was the higher stand height at both sites with 64.11 cm at Chena and 59.66 cm at Gimbo site. Plant height was significantly lower for FG9-09 (44.66 cm) at the Chena site and FG10-09 (45.66 cm) at Gimbo site. This may be a result of genetic variability, soil fertility, adaptability of the varieties to that specific environmental condition, and competition for sunlight between the plants contributing to the difference in height. A similar finding was reported by in the contrary to the present study was reported Walie *et al.* (2016). Variation among tested genotypes in plant height could be due to genetic and environmental factors, such as soil characteristics, moisture conditions, temperature, humidity, pest and disease occurrence, and management of the trial field.

Leaf and stem percentage

The combined analysis of variance showed that the effect of genotypes on leaf and stem biomass was significantly different (P>0.05) at both locations. As shown in Table 4, Hunter river had the highest leaf and stem yield (2.13 t/ha and 3.26 t/ha) respectively at Chena. The leaves and stem yield, which varied depending on maturity at harvest, handling, the number of cuts, and rain damage harvest cycles; which is an important quality indicator during the evaluation of herbage quality and for the selection of appropriate forage cultivar. Significant genotype differences in leaf and stem yield were observed in the present study. However, the results reported by Mekuanint *et al.* (2015) were contrary to the present study.

Yield and yield-related parameters

Green biomass and dry matter yield

The fresh weight of the cut biomass was recorded just after mowing using field balance. The mean combined analysis result of green biomass yield (t/ha) of alfalfa varieties tested at Chena and Gimbo locations is presented in Table 4. The result indicated that there was a statistically significant (P<0.05) difference among the cultivars tested in green biomass yield (t/ha) in Gimbo but not for the Chena site. The highest green biomass yield was obtained from Hunter river (18.56 t/ha) followed by FG9-09 (16.93 t/ha), while Pioneer 1995 (14.66 t/ha) had the lowest biomass yield at the Chena site. In Gimbo site Hunter river had the highest biomass yield (14.13 t/ha) and Magna 788 (9.5 t/ha) had recorded the lowest biomass yield compared to other cultivars. This could be attributed to the genetic differences of the different cultivars. However, Teshale and Ketema (2021) reported as the Hunter river gives the lowest biomass yield. This could be attributed to the differences in environmental temperature and precipitation at different locations. The mean dry matter yields of alfalfa genotypes over locations were presented in Table 4. The highest dry matter value was recorded for Hunter river (5.4 t/ha) followed by FG9-09 (4.43 t/ha) at the Chena site. The present finding was contrary to Mekuanint *et al.* (2015). The mean value for the dry matter yield was 4.19 t/ha at Chena and 3.04 t/ha at Gimbo, this may be due to soil fertility, acidity, moisture content of the soil, and other factors. Variations in the yields could be attributed to the agro-ecological and edaphic divergence with the study area.

Seed yield

There was no recorded seed yield in all varieties of alfalfa at both locations. This may be due to the strong acidity of the soil and the small amount of mineral availability in the soil like potassium and phosphorus, which was very important for alfalfa seed production. When soils are acid, with a pH of 6.2 or lower, alfalfa plants do not grow as well aluminum and possibly Manganese toxicities can limit alfalfa yields. At a low pH, alfalfa roots are less able to absorb nutrients from the soil. Moreover, the nodules on alfalfa roots that convert nitrogen from the air into nitrate the plants can use have difficulty forming and working effectively in acid soils. One with light but frequent summer rains is considered a factor influencing alfalfa seed production.

Farmer preference

Adaptability test for released varieties is very crucial, especially for those studying in a few locations during variety development. Famers' participation in variety evaluation provided a multitude of advantages such as speeding up of the adoption, dissemination, and sustainability of released varieties; reducing the costs of variety development, helping to include farmers' traits that are not considered by researchers, and assisting to exploit their indigenous knowledge of selecting adaptive varieties that meet their interests.

These farmers put their opinion based on the performance of the experimental varieties. They considered early establishment at the field level, uniform appearance, reaction to diseases, and occurrence of insects, leafiness, and biomass yield as a criterion. Based on their evaluation criteria, they grouped Hunter river in the first rank, FG9-09 as second, and FG10-09 as third due to high biomass yield, ease to management, greenness, and other parameters for both locations.

CONCLUSION

All varieties of alfalfa were well adapted with different performance under Gimbo and Chena environmental conditions and those selected varieties can be used as an alternative feed source during feed shortage season in the study areas and other similar areas. The study showed that Hunter river followed FG9-09 and FG10-09 varieties had higher dry matter yield, resistance to diseases, higher green fodder, and ranked as priorities by farmers, experts, and other participants during mini field day. This information can help in the adoption of these varieties for increased forage production in low-input cropping systems highland of the Kafa zone and similar agro-ecologies of the country.

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