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Adaptation Trial of Alfalfa (*Medicago sativa*) Varieties in Selected Districts of West Hararghe Zone, Oromia, Ethiopia

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Abstract— *The experiment was conducted in West Hararghe Zone, Oromia, Ethiopia mid to highland agro-ecologies for two consecutive major cropping seasons, 2020 to 2022 years aimed to evaluate, identify and recommend the best adaptable, high biomass yielders and drought tolerance alfalfa varieties for the study area. Five alfalfa varieties were used as experimental treatments in a randomized complete block design (RCBD) with four replications. All agronomic and yield parameters (50% flowering date, disease incidence, pest incidence, stand vigor, plant height, green biomass yield, leaf stem ratio, dry matter yield and plant height) showed statistically significant ($p<0.05$) variation among varieties except plot cover. The highest mean dry matter yield was recorded for Arba Rakate FTC (5.51 t/ha), Kuni Segeria (3.62 t/ha), and on station (3.42 t/ha) with a combined mean of 4.18t/ha. The highest combined mean dry matter was recorded from the variety Hair Peruvian (4.82 t/ha) followed by Magna#788 (4.16 t/ha) and the lowest dry matter was recorded from Magna#801 (3.9 t/ha) and the fresh biomass yield varied from 14.02 to 17.34 t/ha with the average of 15.16 t/ha that the highest mean fresh biomass yield recorded from Hair Peruvian (17.34t/ha) followed by hunter river (15.30 t/ha) and the lowest recorded from Magna#801 (14.02 t/ha). The combined mean plant height ranged from 68.6 to 82.65 cm with a mean of 78.95 cm. The highest combined leaf- to-stem ratio was recorded from Magna#801 (60.73) followed by Magna#788 (54.06) and the lowest was recorded from Hunter river (49.53). The mean disease occurrence varied from 1.18 to 1.88. The most susceptible varieties were Magna#788 (1.88) and Magna#801(1.81) while the tolerance varieties were werer (1.18) and Hair Peruvian (1.25). From this study, it is concluded that Hair Peruvian followed by Hunter River were found more promising in terms of agronomic traits, DM yield, and fresh biomass yield than others during the main rainy season and popularized as an alternative feed resource under smallholder conditions in the study areas and other places of similar climatic and edaphic conditions*.

Keywords— *Alfalfa varieties, Dry matter yield, fresh biomass and west Hararghe*.

I. INTRODUCTION

Ethiopia has the largest livestock population in Africa, with 66.26 million cattle, 38.01 million sheep, 45.71 million goats, 6.97 million camels, 41.35 million chickens, 10.02 million donkeys, 0.35 million mules, 2.13 million horses and 5.98 million bee hives [31]. The national herd supports, at least in part, the livelihoods of more than 11.3 million rural households, including 27– 35% of the highland livestock keepers, and a large proportion of the lowland herders, who live below the Government of Ethiopia established poverty line [20]. The sector contributed up to 40% of agricultural gross domestic product (GDP), nearly 20% of total GDP, and 20% of national foreign exchange earnings [29]. The productivity of this sector is constrained by several factors, including poor quality and varying seasonal availability of feed, poor genetics, low reproductive performance, high disease incidence and parasite challenges, and low accessibility to services and inputs [30]. Green pasture (55.2%) and crop residues (30.8%) are the main feed types available in the country. The available feed resources in the mixed crop-livestock production areas are natural pastures, crop residues, and to a lesser extent, improved forage, concentrates, and nonconventional feeds [7]. Animals are fed on crop stubble during harvesting seasons. In some places, improved forage is cultivated and fed to dairy cows to increase milk production, but this practice is not widespread [8].

Among the improved forage alfalfa is the most influential in animal production industry. It is the most widely cultivated forage legume worldwide [17] and is widely known as the "queen of the forages" due to its ability to consistently produce high-yielding, high-quality, persistent, profitable potential if given adequate management and adaptability to different climatic conditions [26] and [16] and the most important forage legume in the world, grown in more than 30 million hectares [5]. It is a valuable crop because of numerous agronomic and environmental advantages in terms of preserving soil fertility and biodiversity, soil erosion protection, mitigation of climate change impacts, reduction of groundwater nitrate pollution, fossil fuel consumption, greenhouse gas emissions [28]; [21]. Alfalfa is one of the most palatable forages, providing high energy and protein for dairy and beef cows as well as other types of livestock. It is an "engine of human food production," eventually transformed into milk, cheese, and meat, wool and honeys [17].

Livestock production is one of the major components of agriculture in Ethiopia, and it is highly dependent on the quantitative and qualitative adequacy of feed resources [3]. Feed shortage has been a chronic problem for animal production in pastoral area of Ethiopia [9]. To reduce the nutritional constraints on livestock productivity, the use of adaptive, high yielding, and drought-tolerant improved forages

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of high quality is important [3]. The major livestock feed resources in Ethiopia are crop residues, natural pasture and crop aftermath. West Hararghe feed shortage is accounts 75.7%, animal health (4.8%) and feed cost (3%) [1]. According to finding of [10] and [12] feed shortage is the first constraints for livestock keepers in various parts of West Hararghe Zone.

Hence, introducing different improved forage through adaptation is the quick and inclusive mechanisms in the study area. Among the improved forage crops alfalfa (Medicago sativa L.) could play an important role in providing a significant amount of quality forage, both for the smallholder farmer as well as intensive livestock production systems with appropriate management practices. So, this activity was initiated with the objective of to evaluate, identify and recommend the best adaptable, high yielder and drought tolerance alfalfa varieties for the study area

II. Materials And Methods

Description of the study area

The study was conducted in West Hararghe zone mid to high land parts which include Chiro, Gemechis from high land and Daro Lebu from mid land district as alfalfa has wide range of agro ecologies adaptation [17] These districts are describes as follow:-

Chiro district is located at 9°05′N and 40°52′E. with an average altitude 1826 above sea level. Chat is an important cash crop of this district. Coffee is another important cash crop, with over 5,000 hectares is planted with this crop [12]. The district is mainly characterized by steep slope and mountains with rugged topography, which is highly vulnerable to erosion problems [11]. It has maximum and minimum mean rainfall of 1800 and 900 mm respectively [15]. It has maximum and minimum mean temperature of the district is of 28 °C and 13 °C respectively with annual mean of 21 °C [32].

Daro Labu district is located at latitude of 40°30′ E and 8°10′ N and Mecahara Agriculture Research Center found at 08° 35’ E longitude and 40° 19’ latitude with an altitude of 1,700 m above sea level. The district is located at 434 km and 111km to East of capital city of the country, Addis Ababa and Chiro, capital city of the zone respectively. The major soil texture of the center is sandy loam with reddish color. The ambient temperature of the district ranges from 14 to 26°C with the average of 20°C with average annual rainfall of 1094 mm/year

Gemachis district is also found in West Hararghe Zone, Oromia National Regional State, and eastern part of Ethiopia. The district is located about 343 km southeast of Addis Ababa and 17 km from Chiro town, the capital of West Hararghe Zone. It is located at 8°10′N latitude and 40° 45′E longitude longitudes in the East. The district covers an area of 77,785 ha and it has 35 rural kebeles and 3 urban administrative towns [13].

Experimental design and layout

The experiment was conducted under rain fed conditions during the main cropping season fortwo consecutive (2020 – 2022) years in selected districts of West Hararghe zone. Accordingly, three districts, which includes Gemechis, Chiro and Daro Lebu were selected and used to conduct this experiment. From Gemechis: Kuni segeria FTC, from Chiro: Arba Rakate FTC and from Daro Lebu: Mechara Agricultural Research Center, on station was used as experimental sites. The planting material used for this was five alfalfa varieties which include Werer, Magna#788, Magna#801, Hair Peruvian and Hunter river varieties collected from Werer and Adami Tulu Agricultural Research Center. After the sites had been selected, land preparation was started from April to June through tractor for first time and oxen at second and third times. The sowing date was at the first week of July with plot size of 2*2m using a randomized complete block design (RCBD) with three replications. The space between block, plot and row was 1m, 1m and 0.25m respectively. 8kg/ha seed rate was used through hand drilling with fertilizer rate of 100 kg/ha NPS and 50 kg/ha UREA at the time of sowing. All other crop management practices like weeding, hoeing and guarding were done uniformly to all plots as required.

Data Collection

The collected data for the trial was included 50% flowering date, disease incidence, pest incidence, stand vigor, plant height, green biomass yield, leaf stem ratio, dry matter yield and plant height. From each plot, 220 gram samples of Alfalfa varieties were taken and dried in a forced draft oven dry at 105°C for 24 hours to get constant weight of dry matter yield.

Model and Statistical Analysis

Agronomic data was analyzed using ANOVA by the general linear model procedure of [22] version 9.0. Means were separated using Least Significant Difference (LSD)at 5% significant level.

The model: $Yijk = \mu + Gi + Ej + Bk(j) + (GE)ij + eijk$

Where Gi = Variety effect, Ej = Environmental effect, Bk(j) = Block effect, GEij = Variety and Environment interaction, μ = the overall mean and eijk = random error

III. Results And Discussions

The results of the analysis of variance indicated significant effects of alfalfa varieties on most of the tested variables (Table 1). The interaction effect of varieties, locations and years were showed highly significant ($p<0.001$) variation for 50% flowering, disease incidences, pest incidence, stand vigor, plant height, green biomass yield, Leaf stem ratio and dry matter yield. However, no significant ($p>0.05$) differences were observed for plot cover among the varieties. Varieties were highly significant ($p<0.001$) variations between the years for all parameters. This might be due to the variations of rainfall distribution during the experimental years. Similarly, highly significant ($p<0.001$) variations observed between the years for almost all parameters except plot cover and green biomass yield which was showed non-significant difference. The mean square of location also showed a significant ($p<0.05$) variation on all parameters except plot cover and dry matter yield.

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Table 1: Combined Analysis MSS of ANOVA for agronomic parameters

Source Variation	DF	FD	DI	PI	PC	SV	PH	LSR	BMtha	DMtha
Varieties	4	7.39^{NS}	1.58^{***}	0.82^{***}	1762.61^{***}	8.29^{***}	989.75^{***}	313.17^{**}	50.85^{*}	2.81^{*}
Replication	3	4.97^{NS}	0.35^{NS}	0.21^{NS}	128.81^{NS}	0.15^{NS}	136.95^{NS}	143.91^{NS}	25.27^{NS}	0.52^{NS}
year	1	884.5^{***}	24.2^{***}	21***	610.51^{NS}	7.81^{**}	1230.09^{**}	17282.2^{***}	21.82^{NS}	76.4^{***}
Location	2	4774^{***}	31.25^{***}	30.01^{***}	918.01^{NS}	7.81^{**}	8366.09^{***}	1169.15^{***}	1895.6^{***}	0.79^{NS}
Variety*loc.	8	15.98**	0.49NS	0.76***	169.77^{NS}	0.99^{NS}	108.13^{NS}	45.41**	82.97NS	1.83^{NS}
Variety *year*loc	14	132.16^{***}	1.36^{***}	1.03^{***}	249.98^{NS}	1.26^{*}	600.67^{***}	427.42^{***}	54.09^{*}	3***

NS = Non-significant, * = (p<0.05), ** = (p<0.01), *** = (p<0.001), DF = degree freedom, 50%F = 50% flowering date, DI= disease Incidence, PI = pest incidence, PC= plot cove, SV= stand vigor, PH= plant height in cm, GBMYtha = Green biomass yield tone/ha, LSR = Leaf stem ratio, DMtha = dry matter yield tone/ha and PH = plantheight in cm.

Table 2: Mean Dry matter and Fresh biomass yield of Alfalfa varieties tested across locations

Varieties	Dry matter yield (t/ha)				Fresh biomass yield (t/ha)			
	On station	A/Rakate FTC	K/Segeria FTC	Combined mean	On station	A/Rakate FTC	K/Segeria FTC	Combined mean
Werer	3.38	5.25	3.57^{b}	4.07^{b}	8.98	16.7	17.8^{bc}	14.49^{ab}
Magna#788	3.36	6.32	2.81^{b}	4.16^{b}	9.15	20.6	14.2^{c}	14.65^{b}
Magna#801	3.53	4.85	3.33^{b}	3.9^{b}	9.48	15.4	17.19^{bc}	14.02^{b}
Hair Peruvian	3.54	6.03	4.9^{a}	4.82^{a}	9.13	19.1	23.8^{a}	17.34^{a}
Hunter river	3.31	5.09	3.51_{b}	3.97^{b}	8.48	16.55	20.88^{ab}	15.30^{ab}
Mean	3.42	5.51	3.62	4.18	9.04	17.67	18.78	15.16
CV (%)	23.65	25.48	23.83	24.32	24	23.9	29.24	31.38
LSD (0.05)	0.83	2.16	0.89	0.86	2.23	6.51	5.63	3.79
P level	NS	NS	***	***	NS	NS	*	***

FTC = farmer training Center, NS = Non-significant, * = (p<0.05), ** = (p<0.01), *** = (p<0.001), CV= CV= Coefficient variation, LSD = Least Significant difference, A/Rakate= Arba Rakate, K/segeria=Kuni Segeria

Dry Matter And Fresh Biomass Yield

Forage dry matter yield and fresh biomass yield did not showed significant (P>0.05) variation among the tested alfalfa varieties across the locations except the Kuni Segeria FTC (Table 2). The result indicated that the highest mean dry matter yield recorded from on station was (3.42 t/ha), Arba Rakate FTC (5.51 t/ha) and Kuni Segeria (3.62 t/ha). Combined analysis indicated that dry matter yield varied significantly (P<0.05) among the tested varieties. The significant varieties differences were observed for dry matter yield of alfalfa. This result is in line with reports of[14]; [24]; [9]. From the present findings, dry matter yield ranged from 3.9 to 4.82 t/ha with a mean of 4.18 t/ha. This finding is lower than the mean yield of 6.46 t/ha reported by [14], 6.5 t/ha reported by [9], 7.01 t/ha reported by [24] and 20.46 reported by [4]. The reverse, dry matter yield ranged from 1.78-3.23 t/ha [2] and from 0.67-2.16 t/ha were reported by [6] which were indicated lower than the present findings. Generally, Hair Peruvian was gave the highest dry matter yield and fresh biomass and fresh biomass yield (t/ha) yield. The wide range of dry matter yield observed in different research findings could be attributed to varietal and environmental differences, their interactions, harvesting stage, soil types, management practice and other biotic and abiotic factors.

Combined analysis indicated that fresh biomass yield varied significantly (P<0.05) among the tested varieties. The highest mean fresh biomass yield recorded for Hair Peruvian (17.34t/ha) followed by Hunter river (15.30t/ha) and the lowest mean fresh biomass was recorded for Magna#801(14.02t/ha with the average of 15.16 t/ha.

Generally, Hair Peruvian gave the highest fresh biomass yield. The present finding is lower than the mean yield 37.95t/ha reported by [27]; 29.83 t/ha reported by Denbela, (2015); 66.18 t/ha reported by [25] and 78.16t/ha reported by [4]. This high forage production difference from other findings indicatedthat other potential varieties are must be evaluated for the study area and the significant variations reported by different authors on the forage dry matter yield and fresh biomass yield at different locations might be due to environmental differences, rainfall conditions, soil nutrient status, and genetic variation.

Plant Height And Leaf Stem Ratio

Mean plant height of alfalfa varieties were significantly (P<0.05) different across all testing locations (Table 3). The result showed that the tallest mean plant height recorded for on station (56.32 cm), Arba Rakate FTC (78.95 cm) and Kuni Segeria FTC (76.77 cm). Hair Peruvian variety produced the tallest plant height (66.48 cm) at on station while Werer produced the tallest plant height at Arba Rakate FTC (82.65 cm) and Kuni Segeria FTC (85.65cm). On the other hand, Magna#801 produced the shortest plant height at on station (47.7 cm) and Arba Rakate FTC (68.6 cm) while Hunter river produced the shortest at Kuni Segeria (73.61 cm). The result of combined analysis for plant height was indicated significance (P<0.05) differences. The average value of plant height ranged from 68.6 to 82.65 cm with a mean value of 78.95 cm. The mean plant height of the present result is lower than the report of [23] 89.7 cm, [27] 80.4 cm. However, the result was higher [25] who reported 63.94 cm, and [4] 52.61 cm. This variation could be due to the differences in moisture content, and soil fertility condition of the testing locations. Generally, variety Magna#788 gave the highest mean plant height followed by Werer while Hunter river gave the lowest plant height.

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The mean leaf stem ratio were no showed significantly (P>0.05) variation at two locations (on station and Arba Rakate FTC) however, significance (P<0.05) variation were recorded from Kuni Segeria FTC. But the combined mean of leaf stem ratio of alfalfa varieties were showed significantly (P<0.05) different (Table 3). The highest combined leaf to stem ratio was recorded from Magna#801 (60.73%) followed by Magna#788 (54.06%) and the lowest was recorded from Hunter river (49.53%). The present finding is in line with the findings of [23] who reported the average value of leaf to ration in range of 0.54 to 0.7.

Diseases And Pest Infestation

Mean diseases occurrence and pest infestation of alfalfa varieties were showed significantly (P<0.05) different at all experimental sites except at Arba Rakate FTC but the combined mean disease and pest infestation showed significantly (P<0.05) variation for all research sites (Table 4). The diseases recorded were Lepto leaf spot and Stemphylium leaf spot. The mean diseases occurrence varied from 1.18 to 1.88. Relatively susceptible varieties were Magna#788 (1.88) and Magna#801(1.81) while the tolerance varieties were werer (1.18) and Hair Peruvian (1.25). [23] reported that Magna- 801-FG and Peruvien DZF- 406 were resistant to diseases that showed Peruvien are most tolerant that similar with the present findings. The findings of [23] also indicated that disease occurrence of alfalfa varieties ranged from 0.7 to 2.17.

Table 3: Mean plant height (cm) and Leaf stem ratio of Alfalfa varieties tested across locations

Varieties	Plant height (cm)				Leaf stem ratio			
	On station	A/Rakate FTC	K/Segeria FTC	Combined mean	On station	A/Rakate FTC	K/Segeria FTC	Combined mean
Werer	59.5^{ab}	82.65^{a}	85.65^{a}	82.65^{a}	55.63	48.75	45.63^{bc}	50.63^{b}
Magna#788	50.28^{cd}	81.55^{a}	75.1^{ab}	81.55^{a}	56.25	46.25	51.88^{b}	54.06^{b}
Magna#801	47.7^{d}	68.6^{b}	64.4^{a}	68.6^{b}	62.5	48.75	58.96^{a}	60.73^{a}
Hair Peruvian	66.48^{a}	81.05^{a}	85.08^{a}	81.05^{a}	55.63	47.5	48.75^{bc}	52.19^{b}
Hunter river	57.63^{bc}	80.9^{a}	73.61^{b}	80.9^{a}	56.25	46.25	42.81^{c}	49.53^{b}
Mean	56.32	78.95	76.77	78.95	57.25	47.5	49.6	53.43
CV (%)	13.13	9.49	14.28	9.49	16.98	11.29	13.12	16.09
LSD (0.05)	7.59	11.54	11.25	11.54	9.97	8.26	6.68	6.09
P level	***	*	**	*	NS	NS	***	***

FTC = farmer training Center, NS = Non-significant, * = (p<0.05), ** = (p<0.01), *** =(p<0.001), CV= CV= Coefficient variation, LSD = Least Significant difference, A/Rakate= Arba Rakate, K/segeria=Kuni Segeria

Lepto leaf spot Stemphylium leaf spot

Pest infestation is the most factors that reduce both forage quality and quantity. The mean pest infestation varied from 1.06 to 1.56. Relatively varieties attacked by pest (aphids) were Magna#801 and Magna#788 (1.56) followed by Hunter river (1.44) while the lowest pest infestation were recorded from Hair Peruvian (1.06) variety which almost free of pests that similar results with the findings of [18] all alfalfa varieties were less affected by pests as alfalfa has tremendous genetic resistance to many pests.

Seed Yield At Different Harvesting Year

There were a significance (p<0.05) variation in terms of seed yield for two year harvesting at on station. The mean maximum seed yield (737.9 kg/ha) was recorded from Werer alfalfa variety (702.6 kg/ha) followed Hair Peruvian variety whereas the lowest mean seed yield (65.8 kg/ha) was recorded form Magna#801 variety (Table 5). This result is higher than the reports of [19] at first and second (83 -122 Kg/ha) and (180 -250 kg/ha) harvesting year respectively. Alfalfa seed

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yield setting is the major problems in the country as a general that onlyone location (on research station) gives the seeds both research years.

Seed production is increasing from first year to second year harvesting (fig. 1). The yield of perennial crops increases.

Table 4: Mean disease occurrence and Pest Infestation of Alfalfa varieties tested across three locations/environments

Varieties	Diseases Occurrences				Pest Infestation			
	On station	A/Rakate FTC	K/Segeria FTC	Combined mean	On station	A/Rakate FTC	K/Segeria FTC	Combined mean
Werer	1.88^{c}	1.25	0.5^{b}	1.18^{c}	1.88^{c}	1	0.5^{c}	1.19^{bc}
Magna#788	2.75^{a}	1.25	1^{ab}	1.88^{a}	2.63^{a}	1	0.5^{c}	1.56^{a}
Magna#801	2.5^{ab}	1.5	1.13^{a}	1.81^{ab}	2.13^{b}	1	1^{ab}	1.56^{a}
Hair Peruvian	1.63^{c}	1.5	0.88^{ab}	1.25^{c}	1.5^{c}	1	0.63^{bc}	1.06^{c}
Hunter river	2b^{c}	1.5	1^{ab}	1.5^{bc}	1.75^{c}	1	1.15^{a}	1.44^{ab}
Mean	2.15	1.4	0.9	1.53	1.98	1	0.75	1.36
CV (%)	24.18	23.51	56	34.14	21.29	0	55	33.14
LSD (0.05)	0.53	0.51	0.52	0.37	0.43	0	0.42	0.33
P level	***	NS	*	***	***	NS	*	***

FTC = farmer training Center, NS = Non-significant, * = (p<0.05), ** = (p<0.01), *** =(p<0.001), CV= Coefficient variation, LSD = Least Significant difference, A/Rakate= Arba Rakate, K/segeria=Kuni Segeria

Table 5: Mean seed yield (Kg/ha) of Alfalfa varieties tested on research station

Varieties	Harvesting Time		
	First year harvesting (kg/ha)	Second year harvesting (kg/ha)	Combined mean yield (kg/ha)
Werer	98.31^{a}	1377.5^{a}	737.9^{a}
Magna#788	50.75^{ab}	188.1^{c}	119.4^{c}
Magna#801	32.75^{b}	98.8^{c}	65.8^{c}
Hair Peruvian	77.63^{ab}	1327.5^{ab}	702.6^{ab}
Hunter river	80.50^{ab}	597.5^{bc}	339.0^{bc}
Mean	67.98750	717.88	392.93
CV (%)	60.96416	66.12	61.49
LSD (0.05)	63.857	731.27	372.28
P level	*	**	**

NS = Non-significant, * = (p<0.05), ** = (p<0.01), *** = (p<0.001), CV= Coefficient variation, LSD = Least Significant difference

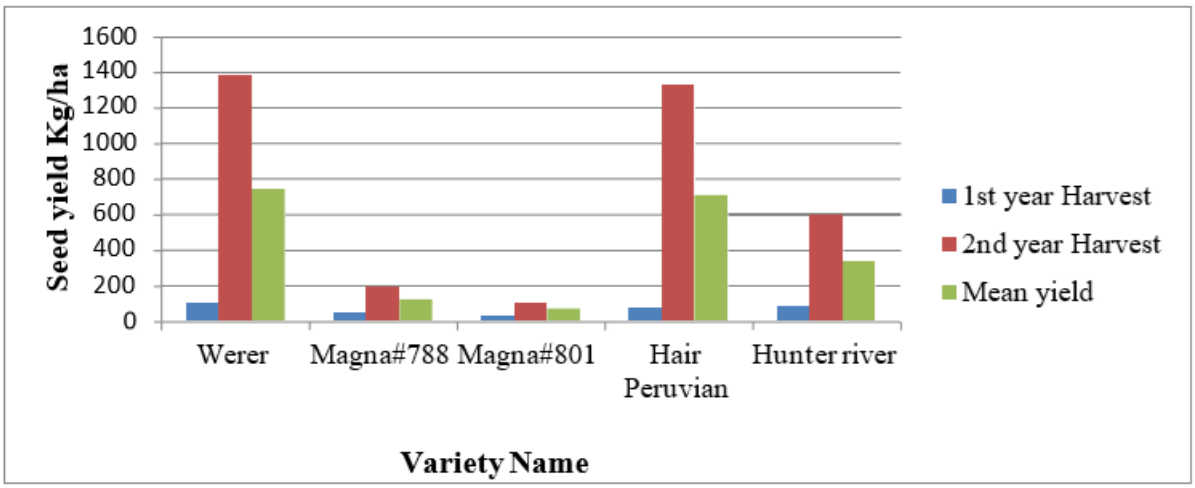

Figure 1: Seed yield (Kg/ha) of Alfalfa Varieties for two harvesting year on station

IV. Conclusions and Recommendations

Livestock production is challenged by animal feed both in terms of quality and quantity in West Hararghe. To solve these challenges, it is important to introduce different improved forage to the study area. Five alfalfa varieties were introduced to evaluate the arability. The highest mean dry matter was recorded from Hair Peruvian (4.82 t/ha) followed by Magna#788 (4.16 t/ha) and the lowest dry matter was recorded from Magna#801 (3.9 t/ha). The fresh biomass yield varied from

14.02 to 17.34 t/ha with the average of 15.16 t/ha that the highest mean fresh biomass recorded from Hair Peruvian (17.34t/ha). The mean diseases occurrence varied from 1.18 to 1.88 that the most susceptible varieties were Magna#788 (1.88) and Magna#801(1.81) while the tolerance varieties were werer (1.18) and Hair Peruvian (1.25). From this study, it is concluded that Hair Peruvian followed by Hunter River

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were found more promising in terms of agronomic traits, DM yield, and fresh biomass yield than others during the main rainy season and popularized as an alternative feed resource under smallholder conditions in the study areas and other places of similar climatic and edaphic

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Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Disclosure

No potential conflicts of interest were reported by the authors

Conflicts of Interest

The authors declare that they have no conflicts of interest

Authors' Contributions

Tamrat Dinkale, the corresponding author, was responsible for all aspects of the study, including data collection, data analysis, and manuscript writing. Muleta Debela and Birmaduma Gadisa were contributed during proposal development; Lensa Urgesa and Jibrail Hassen were contributed from field implementation to data collection and improvement and finalization of the text, as well as reading and approval of the final edition.

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