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Research Article

Effect of Cultivars, Row Spacing and Seeding Rates on Yield and Yield Components of Alfalfa (*Medicagosativa*)

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Abstract

The study was undertaken at Adami Tulu Agricultural Research center (ATARC) with the objectives to evaluate the effect of cultivars, seeding rates and row spacing on yield and yield components of alfalfa. Six alfalfa cultivars (Magna-801, Hunter-river (Check), FG-10-09, Magna-788, FG-09-09 and Alfalfa-Italy), three row spacing (20 cm, 35 cm and 50 cm) and three seeding rates (10, 15 and 20 kg ha^{1-}) were arranged in split-split plot design with three replications. The results indicated that different cultivars influenced significantly the DM yield (P<0.01), leaf to stem ratio (P<0.01) and seed yield (P<0.001) parameters. Comparable DM yield were obtained from FG-10-09, Magna-788, FG-09-09 and Hunter river -(Check) cultivars with values of 1.22, 1.18, 1.09 and 1.08 t/ha respectively. Cultivar FG-09-09 was produced the highest seed yield (21.9 kg ha^{-1}) and it performed well in all other tested parameters. Significantly the highest seed (16.9 kg ha^{-1}) followed by (15.5 kg/ha) were recorded respectively from row spacing of 50 and 35cm. Hence, by considering all agronomic and yield performances, FG-09-09 was selected as best performing cultivar in the study area. Although the highest forage DM yield was produced by the highest seeding rate (20 kg ha^{-1}), since there are no significant differences between seeding rate of 15 kg ha^{-1} and seeding rate of 20 kg ha^{-1}, it is logical to recommend the intermediate seeding rate (15 kg ha^{-1}) with row spacing of 35cm to be the optimal for alfalfa forage production. Thus, it can be concluded that alfalfa cultivar FG-09-09 with intermediate seeding rate of 15 kg ha^{-1}under row spacing of 35 cm proved to be superior with respect to dry matter yield. However, if the target is for seed production, row spacing of 35cm wide with the lowest (10 kg ha^{-1}) seeding rate should be used under Adami Tulu ecological conditions.

Keywords

Alfalfa, Cultivars, Dry Matter Yield, Seed Yield

1. Introduction

Ethiopian's livestock population is the largest in Africa. Despite the large livestock population (60.39 million cattle, 31.3 million sheep, 32.74 million goats, 56.06 million poultry, 2.01 million horses, 8.85 million donkeys, 0.46 million mules and 1.42 million camels), productivity remained too low to satisfy food requirement of the ever-growing human population in the country [1].

Feed scarcity is one of the major technical constraints in livestock production and thus it challenges the economic contribution of the livestock sub-sector. The critical feed nutrient, crude protein (CP), of the herbaceous plants declines during the dry season, leading to prolonged periods of un-

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der-nutrition of livestock reared under such environmental conditions [2]. Moreover, the adoption and use of improved feed technologies remained limited [3], calling for exploring indigenous feed resources [3, 4], giving due emphasis on indigenous knowledge on adapted feed resources in the crop-livestock farming systems. Similarly, in mid rift valley of Oromia, shortage of animal feed resource is identified as one of the major factor limiting the production and productivity of livestock. The existing livestock feed is based on natural pastures, fallow and stubble grazing and crop residues. However, natural pasture and crop residues are poor in quantity and quality [5]. Thus, the obtainable feed resources do not meet the nutrient requirements for growth and reproduction of animals. One of the approaches to alleviate the problem is developing forage species with their agronomic practices for the existing climatic condition.

Alfalfa (*Medicago sativa* L.) is a long-lived perennial forage legume crop and has the ability to stay in soil for 3-5 years producing economical forage yield. Alfalfa performed very well over wide range of environments with productivity determined largely by soil fertility and available water. It is highly productive forage which can be grown under both rainfed and irrigation conditions from the lowlands to highlands. In addition, alfalfa is characterized by its ability to tolerate frequent cutting and produce forage every 20-30 days, add nitrogen to the soil by bacterial nodules in roots, ability to re-growth after cut and store energy in the crown which helps the buds in a quick regrowth [6]. Alfalfa improves the nitrogen content of the soil by fixation and increases the production of crops and other grasses if intercropped and decreases the cost of production and increases the income of small holder farmers by saving the cost of nitrogen fertilizer. Alfalfa is a nutrient rich forage crop that contains high crude protein (CP) which can improves the low nutritive value of crop residues and other native perennial grasses. Besides, alfalfa seed has high demand now days because of increase of dairy production in peri-urban and urban areas of the country by different NGOs and different sector investors.

Under arid and semi-arid agro ecology of mid rift valley of the country, selecting high yielder forage varieties/cultivar, in combination with different agronomic practice such as seeding rate and spacing is mandatory. The seeding rate of alfalfa varies from 2.5 kg to 30 kg ha^{-1} [7, 8] due to differences in environmental, edaphic and seed bed conditions and other factors that could influence germination and establishment. A seed rate of 8-15 kg is recommendable in Ethiopia for a pure stand [9, 10]. Similarly, different spacing between rows (15-60cm) were used at different areas [11].

Considering the importance, a new look at the effect of cultivars, seeding rates and spacing on alfalfa herbage and seed production is very crucial. Hence, the study was designed to evaluate the effect of alfalfa cultivars, seeding rates and row spacing on yield and yield components of alfalfa at Adami Tulu condition.

2. Materials and Methods

2.1. Description of the Study Area

The study was undertaken at Adami Tulu Agricultural Research center (ATARC) on-station site for two consecutive years (2015-2017). The center is located in eastern Shoa zone at about 7 km from Ziway town and 167 km from the capital city of Ethiopia. The altitude of the area is about 1600 meters above sea level (m. a. s. l) and has semi-arid type of climate. The mid rift valley has erratic, unreliable and low rainfall, averaging between 500 and 900 mm per annum. The rain fall is bi-modal with the long rain from June to September [12]. Mean value of the temperature recorded was 21.8 ℃ with a range of 13 to 29 ℃ (ATARC meteorological station, 2010).

2.2. Experimental Design and Treatment

Six selected alfalfa cultivars introduced from abroad were established on finely prepared seed beds. The experiment was arranged in a split plot design with three replication. Six alfalfa cultivars (Magna-801, Hunter-river (Check), FG-10-09, Magna-788, FG-09-09 and Alfalfa-Italy) were used as main plot treatments. While three row spacing (20 cm, 35 cm and 50 cm) and three seeding rates (10, 15 and 20 kg ha-$^{1)}$ were assigned as sub plots and sub-sub plot treatments respectively. The plot size of 3 m x 4 m with a distance between plots and replications of 0.5m and 1 m, respectively was used. Supplemental irrigation was used at dry period of the year and diammonium phosphate (DAP) fertilizer was applied at the rate of 100 kg ha^{-1} at planting. All other management practices were done as per the recommendations.

2.3. Data Collection and Analysis

The major important data recorded were plant vigor, plant height, numbers of tillers per plant, leaf to stem ratio, herbage and seed yield. Plant vigorsity was recorded out of 100% by visual observation from each plot. Plant height was taken from average of five plants randomly selected from each plot and measured from ground level to the tip of the plants. Number of tiller per plant was determined by direct counting of the tillers from five plants that were randomly selected and its average was taken. At full bloom stage, the fresh forage samples were harvested from two rows of each plots and weight just after mowing using field balance. The harvested biomass was manually chopped into small pieces using sickle and a subsample of 500 g was taken and dried in air draft oven at 65 ℃ for 72 hours to determine herbage dry matter yield. A sub sample of 200 gm forage was taken and used for leaf to stem ratio determination. Accordingly the samples were taken and separated into leaf and stem components and weighed to determine leaf to stem ratio. Seed yield was determined by collecting seeds from the two middle rows of each plot when the pods matured. The seeds were threshed and cleaned from unwanted materials and pure seed weight was recorded. All collected data including agronomic parameters, biomass and seed yield were analyzed using the general linear model procedure of SAS [13] version 9.1. Means were separated using least significant difference (LSD) at 5% significant level.

3. Results and Discussion

3.1. Plant Vigor

The analysis of variance indicated that plant vigor was significantly ($P<0.05$) affected by the tested cultivars and row spacing while seeding rates and the interaction between cultivar, row spacing and seeding rates had no significant effect on plant vigor (Table 1). The highest plant vigor (74.81%) was observed for cultivar Magna-788 and it followed by FG-10-09 (69.63%) while the lowest (64.44%) plant vigor value was recorded from Magna-801 cultivar (Table 2). On the other hand, the highest plant vigor (71.48%) was recorded in wider row spacing (50cm) where as the lowest plant vigor (65.92%) had recorded from the lowest row spacing (20cm). The highest plant vigor value observed in wider row spacing might be due to more space, light and nutrients available to the plants in wider row spacing.

3.2. Numbers Tillers

The data on number of tillers per plant was significantly ($P<0.05$) differ among the tested cultivars. On the other hand, row spacing, seeding rate and the interaction between cultivars, row spacing and seeding rate had no significant effect on the number of tillers per plant (Table 1). The result showed that Magna-788 cultivar produced the maximum number of tillers per plant (14.73) while the least value (11.70) was recorded from Alfalfa Italy. Numerically the highest value of tillers per plant (13.39) was recorded for the lowest seeding rate (10 kg ha^{-1}) as demonstrated in Table 2. The reduced number of tillers per plant in increased seed rate might be due to inter plant competition within the rows.

3.3. Plant Height

Plant height was significantly ($P<0.001$) influenced by the main effect of tested cultivars. However, the row spacing, seeding rate and their interaction effect had no significant influence on plant height (Table 1). Mean value of plant height ranges from 36.77-53.06 cm. The tallest plant height (53.06 cm) was recorded for cultivar FG-09-09 whereas the shortest plant height (36.77cm) was recorded for Magna-801 cultivar. The significant varietal differences observed for plant height in the present study was also in agreement with other findings [14]. The difference obtained in the plant height of the tested cultivars might be due to their genotypic variation. [15, 16] also stated variations in plant height to be linked to genotypic differences and environmental factors.

3.4. Leaf to Stem Ratio

As indicated in Table 1, different alfalfa cultivars had significant ($P<0.01$) effect on leaf to stem ratio. Significantly the highest (1.16) leaf to stem ratio was obtained for the FG-10-09 while lowest (0.86) value were recorded for Hunter river (Check) and Alfalfa Italy (Table 2). This may be due to relatively high numbers of branches associated with cultivar FG-10-09 as compared to the other cultivars which were reflected in low leaf portion weight. The variation observed in leaf to stem ratio among the cultivars also verify that the differences of the tested cultivars in their growth and development performances. Leaf to stem ratio is an important trait in the selection of appropriate forage cultivar as it is strongly related to forage quality [17, 18]. Other studies also indicated that seeding rate had little influence on leafiness of alfalfa [19].

3.5. Dry Matter Yield

The result indicated that the tested cultivars and seeding rates had highly significant effect ($P<0.01$) on DM yield while the row spacing and the interaction of cultivar, spacing and seeding rate had no significant differences on dry matter yield production (Table 1). The highest total DM yield (1.22 t ha^{-1}) was recorded from FG-10-09 followed by cultivar Magna-788 (1.18 t ha^{-1}) and FG-09-09 (1.09 t ha^{-1}) per cutting. The least dry matter yield value (0.91t ha^{-1}) was recorded from Magna-801 and Alfalfa-Italy cultivars (Table 2). The DM yield difference among the observed cultivars could be due to their inherent character which enabled them to manifest differently for agronomic and yield parameters in to the prevailing conditions. This indicates that cultivars with better yield are well-adapted to the local environment that allowed the crop to absorb more nutrients and water, resulting in high herbage yield. The significant cultivar differences observed for herbage dry matter yield in the present study concurs with other reports [20, 21]. The wide range of herbage DM yield values observed in different reports could be attributed to varietal or environmental differences and/or their interactions.

Significantly the maximum DM yield (1.13 t ha^{-1}) was recorded from the highest seeding rate (20 kg ha^{-1}) while the least dry matter value (0.98 t ha^{-1}) was obtained from seeding rate of 10 kg ha^{-1} (Table 2). However, the yield obtained from 15 kg ha^{-1} and 20 kg ha^{-1} seed rates were not significantly differ. The non-significant differences between the intermediate (15 kg ha^{-1}) and the highest seeding rates (20 kg ha^{-1}) might be due to competition associated with high seeding rates and the ability of stand provided by the intermediate seeding rate to produce relatively high numbers of shoots per unit area, which compensated for the low seeding rate. Increasing the number of plants per unit area reduces the volume of air and soil that the individual plant can exploit, and therefore increases competition between plants for soil nutrients, carbon dioxide and light [7].

3.6. Seed Yield

The analysis of variance indicated that seed yield was significantly ($P < 0.01$) affected by the tested cultivars and different row spacing ($P<0.05$). However, seeding rate and the interaction effect of cultivar, row spacing and seeding rate did not significantly affected seed yield of alfalfa (Table 1). The maximum seed yield (21.9 kg ha^{-1}) was recorded for cultivar FG-09-09 while the minimum value (10.4 kg ha^{-1}) was obtained from Magna-801 cultivar. The increase in seed yield obtained from FG-09-09 indicating that this cultivar had a better genetic performance as compared to the others tested alfalfa cultivars. The seed yield obtained from the tested cultivars were low when compared with the yield reported by different authors [22]. The main reasons for low seed yield could be poor pollination and floret retention [23]. Studies also indicated that genetic and environmental factors affect seed yield of alfalfa [24].

Significantly the highest seed yield (16.9 kg ha^{-1}) followed by (15.5 kg ha^{-1}) were recorded respectively from row spacing of 50 and 35cm. While the lowest seed yield (30.18 kg ha^{-1}) was obtained from the narrowest row spacing (20 cm). The lower seed yield in the narrowest row spacing could be due to the fewer racemes/m^2. The wide row spacing promotes more branches, flowers per plant, higher percentage seed set, and higher seed yield per plant [25]. Even though different seeding rates did not affected seed yield significantly, the lowest seeding rate produced more seed yield than the two highest seeding rates (Table 2). Other studies also point out that seed yield increased as sowing rate decreased probably due to a greater branch number [26] and subsequently more racemes/m^2. The higher sowing rates probably create greater interplant competition and resulting in a negative effect on seed yield. Literature also indicated that plant density is known to be an important factor in seed production, because competition between and within plants affects a plant's ability to produce vegetative and reproductive material [26]. Moreover, seed yield of alfalfa varies because the growth and development of the seed yield components is strongly affected by the environment.

Studies have reported and recommended different results for optimum row spacing and seeding rate for alfalfa seed production [27, 28] Indicated that the highest seed yield was obtained from 25 cm row spacing with 4 kg ha^{-1} seed rate. Generally, the mean values related to seed yields recorded in this study were lower than those reported by [27]. Variation among the yields may be due to differences in location, climatic conditions (moisture stress) and management techniques under researches were conducted. Hence, the results of this study suggest that among the various row spacing and seeding rates evaluated, row spacing of 35 cm wide with the lowest (10 kg ha^{-1}) seeding rate were found to be optimum for alfalfa seed production under AdamiTulu ecological conditions.

Table 1. *Mean squares of ANOVA's for plant vigor, number of tillers per plant, plant height, leaf to stem ratio, seed and dry matter yield of alfalfa cultivars tested at Adami Tulu.*

Source of variation	Df	PV	NTPP	PH	LSR	DMY	SY
Rep	2	74.82	16.33	85.3	0.104	0.113	2083.5*
Cultivar (Cu)	5	347.87*	35.76*	1039.05***	0.448**	0.446**	2151.5***
Row spacing (RS)	2	427.92*	3.73	10.96	0.196	0.247	757.79*
Seeding rate (SR)	2	271.86	19.13	205.32	0.128	0.294*	111.8
Cu*RS * SR	44	155.86	17.47	97.48	0.089	0.078	163.07
Error	106	204.87	20.44	168.13	0.121	0.155	271.8
Total	161	-					

Where, PV=plant vigorisity; NTPP= Number of tiller per plant; PH= Plant height, LSR= leaf to stem ratio, DMY=Dry matter yield, SY=seed yield,, *= significant at ($P < 0.05$), **= significant at ($p<0.01$), ***= significant at ($P <0.001$)

***Table 2.** Effect of cultivars, row spacing and seeding rates on different agronomic parameters, dry matter and seed yield of alfalfa tested at Adami Tulu condition.*

Treatments	**Parameters**					
	PV (%)	**NTPP**	**PH (cm)**	**LSR**	**DM yield (t ha^{-1})**	**SY (kg ha^{-1})**
Alfalfa cultivars						
Magna-801	64.44^{b}	11.91^{b}	36.77^{c}	0.88^{c}	0.91^{b}	10.4^{d}
Hunter river -(Check)	65.92^{b}	13.35^{ab}	51.32^{a}	0.86^{c}	1.08^{ab}	14.8^{bc}
FG-10-09	69.63^{ab}	12.14^{b}	49.57^{ab}	1.16^{a}	1.22^{a}	15.5^{bc}
Magna-788	74.81^{a}	14.73^{a}	50.55^{a}	0.96^{bc}	1.18^{a}	12.3^{cd}
FG-09-09	68.14^{ab}	12.43^{ab}	53.06^{a}	1.09^{ab}	1.09^{ab}	21.9^{a}
Alfalfa Italy	68.14^{ab}	11.70^{b}	43.28^{b}	0.86^{c}	0.91^{b}	17.1^{b}
Mean	68.5	12.7	47.4	0.97	1.06	15.4
LSD (0.05)	7.46	2.36	6.48	0.18	0.19	3.96
Row spacing						
20	65.92^{b}	12.95	47.15	0.92	1.09	13.6^{b}
35	68.15^{ab}	12.43	47.21	0.95	1.12	15.5^{ab}
50	71.48^{a}	12.76	47.91	1.04	0.99	16.9^{a}
Mean	68.5	12.7	47.4	0.97	1.06	15.3
LSD (0.05)	5.31	NS	NS	NS	NS	3.06
Seeding rates						
10	71.11	13.39	47.17	0.99	0.98^{b}	15.9
15	67.04	12.47	45.23	1.0	1.08^{ab}	14.6
20	67.41	12.27	45.87	0.92	1.13^{a}	15.5
Mean	68.5	12.7	46.09	0.97	1.06	15.3
LSD (0.05)	NS	NS	NS	NS	0.14	NS
CV	20.7	30.1	27.2	30.2	28.3	29.7

Where, PV=plant vigorisity; NTPP= Number of tiller per plant; PH= Plant height, LSR= leaf to stem ratio, DM=Dry matter, SY=seed yield Means followed by the same superscript (s) in the same column for each treatment are not significantly different, LSD= least significant difference, ns=Not significant

3. Conclusions and Recommendations

Alfalfa cultivarFG-09-09 was performed best as compared to the other cultivars in dry matter, seed yield and other parameters. Hence, by considering all agronomic and yield performances, FG-09-09 was selected as best performing cultivars in the study area. Although the highest forage dry matter yield was produced by the highest seeding rate (20 kg ha^{-1}), since there are no significant differences between seeding rate of 15 kg ha^{-1} and seeding rate of 20 kg ha^{-1}, it is logical to recommend the intermediate seeding rate (15 kg ha^{-1}) with row spacing of 35cm to be the optimal for alfalfa forage production. However, if the target is for seed production, row spacing of 35cm wide with the lowest (10 kg ha^{-1}) seeding rate should be used under Adami Tulu ecological conditions. Since this result were only shows the yield and yield components of alfalfa (*Medicago Sativa*), further studies regarding the nutritional composition and its effect on soil fertility are required. Studies that aim to integrate feeds that have better nutritive values into the feeding system are required to further evaluate feed intake, digestibility, level of inclusion (supplementary feeds), animal's responses, and anti-nutritional factors, for more efficient utilization of these well adapted feed resources. Moreover, on-farm evaluation and popularization of the recommended cultivar with its agronomic practice is crucial

Abbreviations

ADF Acid Detergent Fiber
ANOVA Analysis of Variance
DM Dry Matter
CP Crude Protein
CV Coefficient Variation
LSD Least Significant Difference
NDF Neutral Detergent Fiber

Data Availability

Data will be made available on request.

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Authors Contribution

Writing, performed the experiment, and methodology, review and editing.

Conflicts of Interest

The authors declare no conflicts of interest.

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