Research & Development
2021; 2(1): 14-19
http://www.sciencepublishinggroup.com/j/rd
doi: 10.11648/j.rd.20210201.13

Effects of Plant Spacing and Fertilizer Level on Agronomic Performance and Forage Yield of Hybrid *Brachiaria* cv. Mulato II Grass, in Chagni Ranch, Awi Zone, Ethiopia

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To cite this article:
Wondimagegn Tadesse, Berhanu Alemu, Mesganaw Addis. Effects of Plant Spacing and Fertilizer Level on Agronomic Performance and Forage Yield of Hybrid *Brachiaria* cv. Mulato II Grass, in Chagni Ranch, Awi Zone, Ethiopia. *Research & Development*. Vol. 2, No. 1, 2021, pp. 14-19. doi: 10.11648/j.rd.20210201.13

Received: January 5, 2021; **Accepted**: January 29, 2021; **Published**: March 10, 2021

Abstract: Livestock are an important component of nearly all farming systems in Ethiopia. Despite the importance of livestock in the country, productivity is low due to shortage of feed in terms of both quantity and quality, especially during the dry season. A study was conducted to evaluate the effects of plant spacing and N fertilizer application on agronomic performance and dry matter yield of *Brachiaria* hybrid cv. Mulato II grass for the first 150 days after planting under irrigation supplementation in Chagni Ranch, Awi Zone, Ethiopia. A factorial experiment with 3 urea fertilizer levels (0, 50 and 100 kg/ha) and 4 spacings between plants and rows (20 x 20, 30 x 40, 40 x 60 and 50 x 80 cm) with 3 replications was used. Data collected on agronomic characteristics were plant height, number of tillers per plant, number of leaves per plant, leaf: stem ratio basal circumference and dry matter yield (DMY). The highest DMY 9.18 t/ha and 8.93 t/ha were recorded for narrower plant spacing (20 x 20 cm) with higher urea fertilizer level (100 kg/ha) (S1F3) and narrower plant spacing (20 x 20 cm) with medium urea fertilizer level (50 kg/ha) (S1F2), respectively. The current study concluded that, dry matter yield of Mulato II grass can be improved by urea fertilizer application specifically the application of 50 kg/ha urea fertilizer with better economic feasiblity. On the other hand, planting at narrower spacings 20x20 cm were found to have high DMY values and it reduce land shortage problem than other spacings. Similar studies need to be conducted over much longer periods to determine to what extent these findings relate to performance over the life of a permanent pasture.

Keywords: Urea, Spacing, Dry Matter Yield, Chemical Composition

1. Introduction

Livestock are an important component of nearly all farming systems in Ethiopia, providing milk, meat, draught power, transport, manure, hides and skins and serve as a source of cash income [6]. The subsector contributes about 16.5% of the national Gross Domestic Product (GDP) and 35.6% of the Agricultural GDP. It also contributes 15% of export earnings and 30% of agricultural employment. The livestock subsector currently supports and sustains livelihoods for 80% of the total rural population [15]. Despite the importance of livestock in the country, productivity is low [17]. One of the major constraints leading to such low productivity is shortage of feed in terms of both quantity and quality, especially during the dry season [2] combined with high feed prices [17].

In order to solve the shortage of feed and increase livestock productivity, it is necessary to introduce and cultivate high-quality forages with high yielding ability and adaptation to the biotic and abiotic environmental stresses [9]. Improved grasses, many of African origin, have greater palatability and productivity than other indigenous species and are therefore desirable additions to pastures and common grazing areas [5]. Among the improved forage crops introduced into Ethiopia, Mulato II grass, which is the result of crosses of *Brachiaria ruziziensis, B. brizantha* and *B. decumbens*, is claimed to play an important role in providing a significant amount of quality forage [5].

The optimization of production and nutritive value of grass can be achieved by planting on fertile soils [8] and forage management tools such as plant spacing [18]. Nitrogen fertilizer application is a common practice since this nutrient is found to be one of the most limiting factors influencing yield and chemical composition of grass pasture including crude protein (CP) concentration and digestibility, which in turn improves livestock production [11]. Nevertheless, information regarding the effects of fertilizer levels and plant spacing on agronomic performance and biomass yield of Mulato II grass is scarce in our country and specifically in the study area. We conducted the present study in order to generate information on agronomic performance and yield of Mulato II grass at different spacings with different rates of nitrogen fertilizer.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted in Chagni Ranch, Guangua Woreda, Awi Zone, Amhara National Regional State, Ethiopia. Chagni (10°57′N, 36°30′E; elevation 1,583 masl), located at 528 km from Addis Ababa and 186 km West of Regional town, Bahir Dar, is the administrative center of Guangua District [3]. The Ranch is located about 500 m south of the town. The area has average annual rainfall of 1,689 mm and mean minimum and maximum annual temperatures of 23°C and 30°C, respectively (Chagni ranch office).

2.2. Experimental Layout, Design and Treatments

The study was conducted using a 3 x 4 factorial arrangement in a randomized complete block design (RCBD) with 3 replications. The factors were 3 levels of urea fertilizer (0, 50 and 100 kg/ha) and 4 spacings (20 x 20, 30 x 40, 40 x 60 and 50 x 80 cm) between plants and rows, respectively, giving 12 treatment combinations (Table 1) and 36 experimental plots.

Table 1. *Treatment combinations.*

Fertilizer level	Spacing			
	S1	**S2**	**S3**	**S4**
F1	F1 X S1 [T1]	F1 X S2 [T2]	F1 X S3 [T3]	F1 X S4 [T4]
F2	F1 X S1 [T5]	F2 X S2 [T6]	F2 X S3 [T7]	F2 X S4 [T8]
F3	F3 X S1 [T9]	F3 X S2 [T10]	F3 X S3 [T11]	F3 X S4 [T12]

S1=20 x 20 cm spacing; S2=30 x 40 cm spacing; S3=40 x 60 cm spacing; S4=50 x 80 cm spacing between plants and rows, respectively; T=treatments 1-12; F1=0 kg urea/ha; F2=50 kg urea/ha; F3=100 kg urea/ha.

The size of each plot was 3 m long by 3.2 m wide with a gross plot size of 9.6 m^2 and the total experimental area was 12.6 m by 41.5 m (522.9 m^2). The spacings between plots and replications were 0.5 and 1.5 m, respectively. Treatments were randomly assigned to plots within each replication.

2.3. Land Preparation, Experimental Management, Soil Sampling and Analysis

Land was oxen-ploughed, and harrowing and bed preparation were carried out before planting manually. Root splits of Mulato II grass were collected from Finota Selam grass nursery site at an age of 7 months regrowth and planted at the experimental site on 6 September 2017. Urea was purchased from the local market and applied by split application at time of planting and again 30 days after planting with different levels based on treatment. The 25kg/ha for treatment taking 50kg/ha and 50kg/ha for treatment taking 100kg/ha of urea was applied at time of plainting and again 30 days if planting. Weeding was done manually during the experimental period. The experiment was irrigated once a week when rain was limited, withprecautions taken to avoid contamination of treatments by cross flooding. Soil samples were taken by auger from the center and corners of the experimental site prior to planting and from the individual plots immediately after harvesting to a depth of 15 cm. The collected samples were thoroughly mixed, dried, ground and preserved in plastic bags for chemical analysis to evaluate total nitrogen, available phosphorus, pH, organic matter and organic carbon. Total N was determined using the Kjeldahl procedure (Bermner and Mulvaney 1982) and available P using the Olsen method (Olsen et al. 1954). The totan organic carbon of soil was determined based on the Walkely-Black chromic acid wet oxidation method. Organic matter (OM) was calculated indirectly from organic carbon (OC) concentration by multiplying OC by 1.724 and the pH was determined using the method described by Van Reeuwijk (1993).

2.4. Agronomic Data Measurement, Sample Collection and Dry Matter Yield Determination

Data on the agronomic performance and dry matter yield of the Mulato II grass were recorded at harvesting time, 150 days after planting. On 6 February 2018, plant height, total tiller number/plant, total leaf number/plant, leaf:stem ratio and basal circumference were recorded from 10 randomly selected plants. Plant height was measured from ground level to the tip of the main stem using a tape measure. Tiller number per plant was determined by counting the number of tillers on the 10 randomly selected plants per plot. Leaf:stem ratio was determined in each plot by separating leaf and stem portions, air-drying the leaves and stems and weighing separately. Basal circumference (BC) was measured using a piece of rope and a tape measure at 5cm above ground level.

Dry matter yield per plot was determined by hand-harvesting plants in inner rows, i.e. excluding border rows, with 7.28 m^2 for S1, 5.76 m^2 for S2, 4.4 m^2 for S3 and 2.4 m^2 for S4 sampling areas at a height of 5 cm from ground level. Fresh weight of forage was measured immediately after harvesting. The forage was thoroughly mixed and a 0.5 kg fresh subsample was taken from each sample/plot for dry matter yield (DMY) determination. The samples were oven-dried and DMY/ha was calculated using the formula:

DMY (t/ha)=(10 x TFW x SSDW)/(HA x SSFW) (James et al. 2008).

where: 10=constant for conversion of yields in kg/m^2 to tonnes/ha;
TFW=total fresh weight (kg);
SSDW=subsample dry weight (g);
HA=harvested area (m^2); and
SSFW=subsample fresh weight (g).

2.5. Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of the Statistical Analysis System [16]. Differences among treatment means were determined using Duncan's Multiple Range Test (DMRT), at P<0.05. The statistical model used was:

$$Y_{ijk}=\mu + B_i + F_j + S_k + (FS)_{jk} + e_{ijk},$$

where: Y_{ijk}=the response variable
μ=over all mean
B_i=i^{th} block effect
F_j=j^{th} main factor effect (Fertilizer level)
S_k=k^{th} main factor effect (Spacing)
$(FS)_{jk}$=jk^{th} interaction effect (Fertilizer Level x Spacing)
e_{ijk}=random error.

3. Results

3.1. Soil Analysis Report

Soil samples taken before planting of grass revealed the following: organic matter (OM) – 5.88%; organic carbon (OC) – 3.41%; total N – 0.30%; available P – 4 ppm; and pH – 5.6. After harvesting total N of the soil increased slightly with the highest level of urea as compared with the value before planting (Table 2), while pH declined. Available phosphorus (Av. P) declined on all treatments, while both OC and OM concentrations increased (Table 2).

Table 2. *Soil Analysis Report after forage harvest for various urea applications.*

	Soil Parameters				
Treatment	**pH**	**Av. P (ppm)**	**OC (%)**	**OM (%)**	**Total N (%)**
0 kg urea/ha	5.68	2	3.39	5.84	0.29
50 kg urea/ha	5.53	2	3.48	6.00	0.30
100 kg urea/ha	5.48	2	3.85	6.64	0.33
SSBP	5.6	4	3.41	5.88	0.30

SSBF=Soil Sample Before Planting; Av. P=Available Phosphorus; OC=Organic Carbon; and OM=Organic Matter.

3.2. Agronomic Performance of Brachiaria Hybrid (Mulato II) Grass

Overall, there were significant interactions between the effects of the main treatment variables (spacing and urea levels) on agronomic performance and DMY.

3.2.1. Plant Height (cm)

The effects of urea fertilizer level, spacing and their interactions on plant height of Mulato II grass are shown in Table 3. Overall there was no consistent effect of fertilizer level on plant height, although plant height at both levels of urea and the narrowest plant spacing exceeded that at the widest row spacing (P<0.05). Similarly, Plant height on fertilized treatments at the narrowest row spacing exceeded those on the Control treatment.

Table 3. *Plant height (cm) as influenced by urea fertilizer level, plant spacing and their interactions.*

Fertilizer level	Spacing			
	S1	**S2**	**S3**	**S4**
F1	24.7d	31.0bc	28.1cd	24.2d
F2	35.0ab	32.7abc	33.0abc	28.3cd
F3	37.4a	31.3abc	27.4cd	30.4bcd

S1=20 x 20 cm; S2=30 x 40 cm; S3=40 x 60 cm; and S4=50 x 80 cm spacing between plants and rows; F1=0 kg urea/ha; F2=50 kg urea/ha; and F3=100 kg urea/ha.
Means for different treatments with different letters are significantly different (P<0.05).

3.2.2. Tiller Number per Plant

The effects of urea fertilizer level, spacing and their interactions on tiller numbers of Mulato II grass are shown in Table 4. While tiller number/plant increased on all fertilizer treatments as plant spacing increased, differences were significant only for the higher level of urea (P<0.05).

Application of urea fertilizer increased tiller numbers for most row spacings (P<0.05).

Table 4. *Tiller number per plant as influenced by urea fertilizer level, plant spacing and their interactions.*

Fertilizer level	Spacing				
	S1	S2	S3	S4	Mean
F1	32.4d	38.2cd	38.2cd	40.9bcd	
F2	44.7bc	45.0abc	45.6abc	50.0ab	
F3	43.3bc	45.8abc	49.3ab	54.4a	

S1=20 x 20 cm; S2=30 x 40 cm; S3=40 x 60 cm; and S4=50 x 80 cm spacing between plants and rows; F1=0 kg urea/ha; F2=50 kg urea/ha; and F3=100 kg urea/ha.
Means for different treatments with different letters are significantly different (P<0.05).

3.2.3. Leaf Number per Plant

Leaf number per plant, which in part, determines the photosynthetic capacity of the plants, was significantly (P<0.05) affected by spacing, urea fertilizer level and their interactions (Table 5). Number of leaves per plant increased as plant spacing increased at all urea levels (P<0.05) with the highest number of leaves (506.56 leaves/plant) at the widest spacing and the higher level of urea applied. While fertilizer application increased leaf number/plant, differences were significant at only the wider two plant spacings (S3 and S4) (P<0.05).

Table 5. *Leaf number per plant as influenced by urea fertilizer levels, plant spacing and their interactions.*

Fertilizer level	Spacing			
	S1	S2	S3	S4
F1	210.8e	286.3bcde	259.0de	338.0bcd
F2	272.0cde	333.7bcd	384.8b	358.8bcd
F3	293.5bcde	311.1bcde	364.4bc	506.6a

S1=20 x 20 cm; S2=30 x 40 cm; S3=40 x 60 cm; and S4=50 x 80 cm spacing between plants and rows; F1=0 kg urea/ha; F2=50 kg urea/ha; and F3=100 kg urea/ha.
Means for different treatments with different letters are significantly different (P<0.05).

3.2.4. Leaf:Stem Ratio

Leaf:stem ratio was also significantly (P<0.05) affected by spacing, urea fertilizer level and their interactions (Table 6). Leaf:stem ratio was increased by row spacing at all fertilizer levels but differences were significant only for the Control and 100 kg urea/ha treatments (P<0.05). Similarly, urea application increased leaf:stem ratio at all plant spacings but differences were significant (P<0.05) only for the wider two spacings (S3 and S4).

Table 6. *Leaf:stem ratio as influenced by urea fertilizer level, spacing and their interactions.*

Fertilizer level	Spacing			
	S1	S2	S3	S4
F1	1.12e	1.37bcde	1.16de	1.42bcd
F2	1.32bcde	1.27cde	1.38bcde	1.48bc
F3	1.38bcde	1.44bcd	1.59ab	1.82a

S1=20 x 20 cm; S2=30 x 40 cm; S3=40 x 60 cm; and S4=50 x 80 cm spacing between plants and rows; F1=0 kg urea/ha; F2=50 kg urea/ha; and F3=100 kg urea/ha.
Means for different treatments with different letters are significantly different (P<0.05).

3.2.5. Basal Circumference

Table 7. *Basal circumference as influenced by urea fertilizer level, spacing and their interactions.*

Fertilizer level	Spacing			
	S1	S2	S3	S4
F1	29.50^{d}	30.05^{cd}	32.77^{bcd}	33.44^{abc}
F2	32.00^{cd}	33.33^{abc}	33.40^{abc}	34.00^{ab}
F3	34.00^{ab}	34.33^{ab}	34.66^{ab}	37.22^{a}

S1=20 x 20 cm; S2=30 x 40 cm; S3=40 x 60 cm; and S4=50 x 80 cm spacing between plants and rows; F1=0 kg urea/ha; F2=50 kg urea/ha; and F3=100 kg urea/ha.
Means for different treatments with different letters are significantly different (P<0.05).

The basal circumference was significantly (P<0.05) affected by urea fertilizer levels, spacing and their interactions (Table 7). Basal circumference increased as plant spacing increased but the differences were significant (P<0.05) only for Control and the lower urea level. Similarly, urea application increased basal circumference but differences were significant (P<0.05) only at the narrower two plant spacings (S1 and S2).

3.2.6. Dry Matter Yield

Dry matter yield (DMY) per hectare was also significantly (P<0.01) affected by spacing, urea fertilizer level and their interactions (Table 8). Increasing plant spacing reduced DMY of forage at all fertilizer levels (P<0.05) and urea application increased DMY at all plant spacings but differences were significant (P<0.05) only at the narrowest plant spacing. Highest yields were obtained at the narrowest plant spacing with urea applied (P<0.05).

Table 8. *Total dry matter yield (t/ha) as influenced by urea fertilizer level, plant spacing and their interactions.*

Fertilizer level	Spacing			
	S1	S2	S3	S4
F1	6.5b	5.17bcd	4.22de	2.91e
F2	8.93a	5.68bc	4.51cd	4.01de
F3	9.18a	6.46b	4.61cd	3.80e

S1=20 x 20 cm; S2=30 x 40 cm; S3=40 x 60 cm; and S4=50 x 80 cm spacing between plants and rows; F1=0 kg urea/ha; F2=50 kg urea/ha; and F3=100 kg urea/ha.
Means for different treatments with different letters are significantly different (P<0.05).

4. Discussion

The higher dry matter yields at narrower spacing with application of N fertilizer were to be expected as plant population was greater, plants were taller and soil fertility was improved with application of urea fertilizer. A combination of increased tiller numbers and number of leaves per plant could contribute to increased photosynthetic activity and hence higher dry matter production. Similarily, Bouathong et al. [20] reported a trend of hybrid brachiaria grass yield components increment as the level of N fertilizer application increased and have no significance of adding nitrogen levels above 40kg/ha. Additionaly, the dry matter yields of Mulato II grass significantly increased with increasing rates of N fertilizer [11]. The total dry matter yield *Brachiaria decumbens* affected positively as the application of limestone with the use of UK fertilizer [1]. The best results has been obtained with three application of N, particularily in the case of Mulato II, which has increased DM yields from 2.2t/ha per cut with one application of N to 3.1t/ha per cut with three applications [5].

Plant height of Mulato II grass was high at higher feritilzer levels and narrower spacing might be due high levels of N fertilizer application facilitate vegetative growth and narrow spacing makes the plants compete for light which facilitates rapid upward increment in plant. vegetative growth Mulato II generally increased for brachiary cultivars. *Brachiaria humidicola* is a strongly stoloniferous and rhizomatous perennial grass, forming a dense ground cover and has a good ground cover, aggressive growth and decumbent habit [13]. The finding that higher fertilizer level produce longer plant supports the result of Olanite et al. [14], who reported that higher plant height values on Sorghum crop receiving maximum fertilizer level. Similar with current result, Berihun [4] reported longer plant height with higher plant densities in case of Bana grass. However, Nadaf et al. [12] reported opposite effect for *Cenchrus ciliaris, where* mean plant height values was longer at wider row spacing compared to the narrow row spacings.

The current finding that the number of tillers per plant increased as N fertilizer levels and spacing increased might be due to reduction of competition for resources like light, moisture; nutrient and space thereby facilitate tiller initiation within a plant. When plants come close together, the availability of nutrient and water may be limited, which inhibit tiller development. The N fertilizer enhances development of new buds and tillers of grass by increasing soil fertility. Bouathong et al. 2011 showed that N significantly affected tiller numbers of the hybrid brachiaria grass, with 40kg/ha N producting nearly 50% more tillers than plants reciving no N. The increased competition for light causes reduced growth and tillering capacity. Therefore, the competitor plants are forced to grow upright to dominate other tillers rather than expanding laterally by bearing more tillers [7]. Wider spacing allowed light penetrates to be used by lower growing plants and reduce competition for nutrients which may have stimulated tiller development [4].

Leaves are a good nutritional quality parameters for forage grass species. The application of N fertilizer increases soil fertility sufficient to produce more leaves and make the plant grow vigorously. In addition, in the wider spacings, the plants receive more light which could be used for leaf formation but in grass grown on narrower spacings there could be shading effects and resulted in the formation of fewer lateral shoots. The plant having higher tiller numbers contained higher number of leaves/plants. The observed high number of leaves per plant at wider spacing reinforces the finding of Lulie and Chala [10] who reported higher leaf numbers/plant at wider intra and inter row spacings. The increasing of leaf number per plant at wider row spacing was probably due to higher tiller number.

The increasing of leaf to stem ratio at wider spacing (40x60 and 50x80 cm) with the application of higher fertilized levels (100 kg/ha) might be due to the higher leaves observed for these treatments. The reasons might be the presence of higher nutrient and abundant space leading to absence of completion and allowing the plant to have vigorous growth which facilitate more leaf growth. Relatively lower leaf to stem ratios was recorded for narrower spacings due to competition among plants which resulted in an increased steam structures (early maturity) rather than leaves. The current result was supported by the work of Berihun [4] who reported higher leaf to stem ratio of Bana grass from wider spacings compared to narrow planting patterns. Wider spacing extended tillering and lateral growth due to less competition for resources like soil moisture, space, nutrients and light producing more leaf from axial buds at the nodes thereby increasing the proportion of leaves.

Mean basal circumstance was higher at higher N fertilizer levels with wider spacing interaction. The reasons might be due presence of higher tillers which makes the plants to have higher basal circumference. In the wider spacings, plants could take available nutrient for higher tiller formation without being competition among plants. The higher urea level showed the ability to increase absorption of required nutrient which enhanced tillering of plants. Similarly, Tessema et al. [19] reported significantly higher basal circumference values for Napier grass as affected by application of fertilization.

5. Conclusion and Recommendation

The current result revealed that, dry matter yield of Mulato II grass can be improved by urea fertilizer application. More specifically the application of 50 kg/ha urea fertilizer is the most important to provides higher dry matter yield with better economic feasiblity. On the other hand, DMY of grasses at narrower spacings 20x20 cm were found to have high values. Not only this but also it reduce land shortage problem than other spacings. An important limitations of this study, that could be addressed in future works are:

1. The trial needs to be conducted across a years to reach a complete recommend of optimum yield more precisely.
2. Further study on re-growth yield of Mulato II grass is

useful to determine continuing productivity of grass in terms of yield.

3. The trial needs to be conducted for different types of soil to recommend optimum yield of Mulato II grass.
4. Further study on harvesting time and fertilizer type effects on Mulato II grass is useful to determine productivity of the grass in terms of yield.
5. The magnitude of improvement in the yield of Mulato II grass needs to be studied in terms of animal performance.

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