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Short Communication

Effects of plant spacing and fertilizer level on forage yield and chemical composition of hybrid *Urochloa* cv. Mulato II grass during the first 150 days of growth under irrigation supplementation, in Chagni Ranch, Awi Zone, Ethiopia

Efectos del espaciamiento de las plantas y el nivel de fertilizante sobre el rendimiento del forraje y la composición química de la gramínea híbrida Urochloa *cv. Mulato II durante los primeros 150 días de crecimiento bajo riego suplementario, en Chagni Ranch, Awi Zone, Etiopía*

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Abstract

A study was conducted to evaluate the effects of plant spacing and N fertilizer application on dry matter yield and chemical composition of *Urochloa* hybrid cv. Mulato II grass for the first 150 days after planting. A factorial experiment with 3 urea fertilizer levels (0, 50 and 100 kg/ha) and 4 spacings between plants and rows (20 × 20, 30 × 40, 40 × 60 and 50 × 80 cm) with 3 replications was used. Data collected were dry matter yield (DMY), leaf:stem ratio and chemical analyses, i.e. crude protein (CP), ash, neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) concentrations. Results indicated that DMY, leaf:stem ratio, CP%, NDF% and ADF% were significantly ($P<0.05$) affected by interactions between plant spacing and fertilizer level. However, ash and ADL were significantly ($P<0.05$) affected only by main effects. The highest DMYs (9.18 t/ha and 8.93 t/ha) were recorded for narrowest plant spacing (20 × 20 cm) with higher urea fertilizer level (100 kg/ha) and narrowest plant spacing (20 × 20 cm) with medium urea fertilizer level (50 kg/ha), respectively. CP% ranged from 14.6 to 20% and leaf:stem ratio from 1.12 to 1.82:1. Similar studies need to be conducted over longer periods to determine to what extent these findings relate to performance over the life of a permanent pasture.

Keywords: Dry matter yield, N fertilizer, nutrient composition, spacing, urea.

Resumen

Se realizó un estudio para evaluar los efectos del espaciamiento de las plantas y la aplicación de fertilizantes nitrogenados sobre el rendimiento de materia seca y la composición química del híbrido *Urochloa* cv. Pasto Mulato II durante los primeros 150 días después de la siembra. Se utilizó un experimento factorial con 3 niveles de fertilizante de urea (0, 50 y 100 kg / ha) y 4 espaciamientos entre plantas y surcos (20 × 20, 30 × 40, 40 × 60 y 50 × 80 cm) con 3 repeticiones. Los datos recopilados fueron el rendimiento de materia seca (DMY), la relación hoja: tallo y los análisis químicos, como las concentraciones de proteína cruda (CP), ceniza, fibra detergente neutra (NDF), fibra detergente ácida (ADF)

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y lignina detergente ácida (ADL). Los resultados indicaron que el DMY, la relación hoja: tallo, CP%, NDF% y ADF% se vieron afectados significativamente (P <0.05) por las interacciones entre el espaciamiento de las plantas y el nivel de fertilizante. Sin embargo, las cenizas y las ADL se vieron afectadas significativamente (P <0.05) solo por los efectos principales. Los DMY más altos (9.18 t/ha y 8.93 t/ha) se registraron para el espaciamiento de plantas más estrecho (20 × 20 cm) con un nivel de fertilizante de urea más alto (100 kg/ha) y el espaciamiento de plantas más estrecho (20 × 20 cm) con medio nivel de fertilizante de urea (50 kg/ha), respectivamente. El porcentaje de CP varió de 14.6 a 20% y la relación hoja: tallo de 1.12 a 1.82:1. Es necesario realizar estudios similares durante períodos más prolongados para determinar en qué medida estos hallazgos se relacionan con el rendimiento durante la vida de una pastura permanente.

Palabras clave: Composición de nutrientes, espaciado, fertilizante N, rendimiento de materia seca, urea.

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 (Funk et al. 2012). 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 (Leta and Mesele 2014). Despite the importance of livestock in the country, productivity is low (Gebremariam et al. 2010). 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 (Hassen et al. 2010), combined with high feed prices (Gebremariam et al. 2010).

In order to solve the shortage of feed and increase livestock production, introduction and cultivation of high-quality forages with high yielding ability and adaptation to the biotic and abiotic environmental stresses may be an option (Kahindi et al. 2007). 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 (Mengistu 2002). Among the improved forage crops introduced into Ethiopia, Mulato II grass, which is the result of crosses of *Urochloa ruziziensis*, *U. brizantha* and *U. decumbens*, is claimed to have the capacity to provide a significant amount of quality forage (CIAT 2006).

The optimization of production and nutritive value of grass can be achieved by planting on fertile soils and utilizing forage management tools such as plant spacing and utilizing when at high nutritive value (Yiberkew et al. 2020). Nitrogen (N) 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, increases in which improve livestock production (Marques et al. 2017). Nevertheless, information regarding the effects of fertilizer levels and plant spacing on biomass yield and chemical composition of Mulato II grass is scarce in our country and specifically in the study area. We hypothesized that planting the grass more densely and fertilizing with N would produce more dry matter (DM) more rapidly than when planted at wide spacing and not fertilizing. We conducted the present study in order to generate information on yield and chemical composition of Mulato II grass during the first 150 days at different plant spacings with different rates of nitrogen fertilizer.

Materials and Methods

Description of the study area

The experiment was conducted in Chagni Ranch, Guangua Woreda, Awi Zone, Amhara National Regional State, Ethiopia (10°57 ′N, 36°30′ E; 1,583 masl). The area has average annual rainfall of 1,689 mm and mean minimum and maximum annual temperatures of 23 °C and 30 °C, respectively.

Experimental layout, Design and Treatments

The study was conducted using a 3 × 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 × 20, 30 × 40, 40 × 60 and 50 × 80 cm; S1, S2, S3 and S4, respectively) between plants and rows, respectively, giving 12 treatment combinations and 36 experimental plots. Control treatment was regarded as the unfertilized treatment at each plant spacing.

Each plot was 3 × 3.2 m and the total experimental area was 12.6 × 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.

Soil samples were taken by auger from the center and corners of the experimental site prior to planting to a depth of 15 cm and analyses 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.

Land preparation and Experimental management

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 applied by split application with half applied at planting and the remainder at 30 days after planting with different levels based on treatment. Weeding was done manually during the experimental period. The experiment was irrigated once a week when rain was limited, with precautions taken to avoid contamination of treatments by cross flooding.

Sample collection and Dry matter yield determination

Data on dry matter yield (DMY) and chemical composition of Mulato II grass were recorded at harvesting time, 150 days after planting. On 6 February 2018, leaf:stem ratio was determined from 10 randomly selected plants in each plot by separating leaf and stem portions, air-drying the leaves and stems and weighing separately.

DMY per plot was determined by hand-harvesting plants in inner rows, i.e. excluding border rows, with sampling areas of 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 at a height of 5 cm from ground level. Fresh weight of forage was measured immediately after harvesting, before the forage was thoroughly mixed and a 0.5 kg fresh subsample was taken from each sample for DMY determination. The samples were oven-dried and DMY/ha was calculated.

Chemical analysis of forage

Following mixing of the forage a second 0.5 kg fresh subsample was taken from each plot for chemical analysis and dried in a forced-draft oven at a temperature of 105 ºC for 24 hours. The dried material was ground to pass through a 1 mm sieve for chemical analysis and preserved in plastic bags pending analysis at Debre Birhan Agricultural Research Center Animal Nutrition Laboratory. Ash and N were determined according to the procedures described by AOAC (1990) and neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) according to the procedures described by Van Soest (1985).

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS 2007). Differences among treatment means were determined using Duncan's Multiple Range Test (DMRT) at P<0.05. The statistical model used was:

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

Y_{ijk} = the response variable;
μ = overall 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 × spacing); and
e_{ijk} = random error.

Results

Overall, there were significant interactions between the effects of the main treatment variables (plant spacing and urea level) on DMY, leaf:stem ratio and chemical composition.

Dry matter yield and leaf:stem ratio

DMY per hectare was significantly (P<0.01) affected by both plant spacing and urea fertilizer level (Table 1). 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) at only the narrowest plant spacing. Highest yields were obtained at the narrowest plant spacing with urea applied (P<0.05).

Leaf:stem ratio was increased by plant spacing at all fertilizer levels but differences were significant for only the unfertilized Control and 100 kg urea/ha treatments (P<0.05; Table 1). Similarly, urea application increased leaf:stem ratio at all plant spacings but differences were significant (P<0.05) for only the wider 2 spacings (S3 and S4).

Table 1. Total dry matter yield and leaf:stem ratio of *Urochloa* Mulato II at 150 days after planting as influenced by combinations of urea fertilizer level and plant spacing.

Fertilizer level	Plant spacing S1	S2	S3	S4
Total dry matter yield (t/ha)				
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
Leaf:stem ratio				
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 × 20 cm; S2 = 30 × 40 cm; S3 = 40 × 60 cm; and S4 = 50 × 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).

Chemical composition

The significant effects of N fertilizer level, plant spacing and their interactions on crude protein percentage (CP) are indicated in Table 2. CP concentration increased (P<0.05) with increase in row spacing at all fertilizer levels and urea application increased CP% at all plant spacings but differences were significant (P<0.05) at only the narrowest and widest spacings. Highest CP% (20.0%) was recorded where 100 kg urea/ha was applied at the widest plant spacing and the lowest (14.6%) for the unfertilized Control treatment at the narrowest plant spacing.

Table 2. CP, NDF and ADF concentrations of *Urochloa* Mulato II at 150 days after planting as affected by combinations of urea fertilizer level and plant spacing.

Spacing	Fertilizer level S1	S2	S3	S4
Crude protein (%)				
F1	14.6h	16.6fg	17.7cdefg	18.5bcd
F2	16.2g	16.6fg	18.3bcde	19.5ab
F3	17.2defg	18.1bcdef	19.1abc	20.0a
Neutral detergent fiber (%)				
F1	52.8a	51.0ab	48.3abc	45.5bcde
F2	48.5abc	47.8bcd	43.6cde	46.2bcde
F3	45.1cde	42.1e	46.6bcde	42.3de
Acid detergent fiber (%)				
F1	39.3a	38.2ab	36.3bcd	34.4bcde
F2	36.9abc	36.3abcd	30.8de	33.3bcde
F3	33.7bcde	32.1cde	31.0de	30.1e

S1 = 20 × 20 cm; S2 = 30 × 40 cm; S3 = 40 × 60 cm; and S4 = 50 × 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).

Both NDF and ADF concentrations declined as fertilizer level increased but differences were significant (P<0.05) for only the narrower 2 plant spacings (Table 2). Similarly, NDF% declined as plant spacing increased but differences were significant (P<0.05) in the unfertilized Control treatment only. ADF% also declined as plant spacing increased but there were no consistent significant differences. Overall trends were for highest values for both NDF and ADF concentrations to occur in the Control (unfertilized) at the narrowest plant spacing and the lowest values with the higher urea level at the widest plant spacing.

Discussion

The higher DMY 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 have contributed to increased photosynthetic activity and hence higher dry matter production (Damry et al. 2009). Those authors reported that increasing level of urea fertilizer application increased Mulato tiller numbers and DM production plus CP and NDF concentrations. Responses to urea in this study also confirm those of CIAT (2006) that *Urochloa* Mulato II is highly responsive to N fertilizer. Similarly, Bouathong et al. (2011) reported a trend for hybrid *Urochloa* grass yield components to increment as the level of N fertilizer application increased with no significant benefit of adding N at levels above 40 kg/ha. Similarly, Marques et al. (2017) reported DMY of Mulato II significantly increasing with increasing rates of N fertilizer. Yiberkew et al. (2020) reported that DMY of Mulato II hybrid was significantly affected by plant spacing where yields from spacings of 15 × 50 and 30 × 50 exceeded those at 45 × 50 cm at 3 months after planting. Buamool and Phakamas (2018) also reported that DMY of tropical grasses like Mulato II, Ruzi grass (*Urochloa ruziziensis*), Purple guinea (*Megathyrsus maximus* TD 58) and Mombasa guinea (*Megathyrsus maximus* cv. Mombasa) were higher following urea application than with ammonium sulphate or non-fertilized grasses.

Leaves are a good nutritional quality parameter for forage grass species. The application of N fertilizer increases soil fertility sufficiently to produce more leaves and make the plant grow vigorously. In addition, at the wider spacings, the plants receive more light, which could be used for leaf formation but in grass grown at narrower spacings there could be shading effects, resulting in the formation of fewer lateral shoots. Wider spacing reduces competition for light, nutrients and moisture so plants can grow more vigorously, which is stimulated by N application. Relatively lower leaf:stem ratios were recorded for narrower spacings due to competition among plants, which resulted in increased stem growth (early maturity) rather than leaf development. These results support the findings of Yiberkew et al. (2020) that leaf:stem ratio was higher at wider spacing (45 × 50 cm) than at intermediate (30 × 50 cm) and narrow plant spacing (15 × 50 cm) (1.39, 1.1 and 0.97, respectively).

While Mulato II showed good response to N fertilizer, depending on the level of soil fertility, one or more maintenance applications may be required to maintain high yields of good quality forage. Nutritive value of forage, i.e. concentrations of CP, ADF, NDF and digestibility, depends on soil fertility and stage of maturity. Planting Mulato II at wider plant spacings with higher N fertilizer level produced excellent nutritional value, particularly CP%, which is often a limiting nutrient in forages. Forage produced at all plant spacings with urea fertilizer application had CP concentration well above the level required for effective rumen function (7.5%) (Van Soest 1982) and for lactation (15%) (Norton 1982). This is a clear indication of the value of this particular grass as a forage for livestock. Factors contributing to the higher CP percentage at higher fertilizer level and wider plant spacing would be higher N uptake by individual plants, plus enhancement of leafiness and leaf:stem ratio of grass. This would agree with findings of Marques et al. (2017), who reported that application of N produced a significant increase in forage production and a linear increase in CP% of Mulato II.

NDF and ADF concentrations all declined as N fertilizer level and spacing increased. This would be a function of reduced stem percentage and reduced lignification at the wider spacing and with greater N availability in fertilized treatments. At lower fertilizer levels and narrower plant spacing, competition between plants for resources forces plants to prioritize development of structural components to cope with the environmental conditions. The current result is in line with Marques et al. (2017), who reported that higher fertilizer doses led to higher protein and lower NDF and ADF concentrations in Mulato II, which should increase nutritive value of grass and its intake. Increase in cell wall contents (NDF) is a very important limiting factor in terms of nutritive value of feeds (Van Soest 1985). NDF values greater than 60% result in decreased voluntary feed intake, increased rumination time and decreased conversion efficiency of metabolizable energy (Reed and Goe1989). All forage produced in this study had NDF concentrations below the critical value of 60%.

The current results revealed that DMY of Mulato II during the first 150 days of growth can be improved by urea fertilizer application. More specifically application of 50 kg urea/ha produced good responses in both DMY and CP concentration. While higher urea levels produced further increases in both parameters, the financial return was unlikely to be positive given the lower response with the extra amount of fertilizer applied. Similarly closer spacing of plants, i.e. closer planting, resulted in higher yields of forage at reduced CP%.

It must be remembered that this study covered only the first 150 days of growth, which is a very short time in the life of a perennial pasture. While narrow spacing resulted in additional forage growth in this early stage, it would be expected that, as the stand matured, differences in yield between different spacings would disappear. Future studies should be continued for at least 2 years to test this, while a range of harvest frequencies and maintenance fertilizer levels should be examined. Repeating these studies on a range of soil types and under differing environmental conditions will determine how applicable the results are over a range of conditions, while the true benefits of growing this grass will only be known when performance of animals consuming the forage is assessed.

References

(Note of the editors: All hyperlinks were verified 31 August 2021).

AOAC. 1990. Official methods of analysis of Association of Official Analytical Chemists. 15th Edn. AOAC, Washington, DC.

Bouathong C; Hare M; Losirikul M; Wongpichet K. 2011. Effect of nitrogen rates on plant growth, seed yield and seed quality of three lines of *Brachiaria* hybrid grass. Khon Kaen Agricultural Journal 39:295-306.

Buamool P; Phakamas N. 2018. Effects of different forms of nitrogen fertilizer on growth and yield of four tropical pasture grasses. International Journal of Agricultural Technology 14(7):1065-1076. bit.ly/38SnxwK

CIAT (Centro Internacional de Agricultura Tropical). 2006. CIAT Annual Report 2005. Project IP-5. Tropical Grasses and Legumes: optimizing genetic diversity for multipurpose use. CIAT, Cali, Colombia. bit.ly/3tuFGKG

Damry; Marsetyo; Syukur SHj. 2009. Growth, production and nutritive value of *Brachiaria* mulato as affected by levels of urea fertilization. Proceedings of the 1st international seminar on animal industry, Faculty of Animal Science, Bogor Agricultural University. repository.ipb.ac.id/handle/123456789/33826

Funk C; Rowland J; Eilerts G; Kebebe E; Biru N; White L; Galu G. 2012. A climate trend analysis of Ethiopia. Fact Sheet 2012–3053. U.S. Geological Survey, Reston, VA, USA. doi: 10.3133/fs20123053

Gebremariam S; Amare S; Baker D; Solomon A. 2010. Diagnostic study of live cattle and beef production and marketing. Constraints and opportunities for enhancing the system. Bill & Melinda Gates Foundation and Ethiopian Agricultural Transformation Agency, Seattle, WA, USA and Addis Ababa, Ethiopia. hdl.handle.net/10568/24698

Hassen A; Ebro A; Kurtu M; Treydte AC. 2010. Livestock feed resources utilization and management as influenced by altitude in the Central Highlands of Ethiopia. Livestock Research for Rural Development 22, Article#229 lrrd.cipav.org.co/lrrd22/12/hass22229.htm

Kahindi RK; Abdulrazak SA; Muinga RW. 2007. Effect of supplementing Napier grass (*Pennisetum purpureum*) with Madras thorn (*Pithecellobium* dulce) on intake, digestibility and live weight gains of growing goats. Small Ruminant Research 69:83–87. doi: 10.1016/j.smallrumres.2005.12.008

Leta S; Mesele F. 2014. Spatial analysis of cattle and shoat population in Ethiopia: growth trend, distribution and market access. SpringerPlus 3:310. doi: 10.1186/2193-1801-3-310

Marques DL; França AFS; Oliveira LG; Arnhold E; Ferreira RN; Correa DS; Bastos DC; Brunes LC. 2017. Production and chemical composition of hybrid *Brachiaria* cv. Mulato II under system of cuts and nitrogen fertilization. Biological Science Journal 33:685-696. doi: 10.14393/BJ-v33n3-32956

Mengistu A. 2002. Forage Production in Ethiopia: a case study with implications for livestock production. Ethiopian Society of Animal Production, Addis Ababa, Ethiopia. hdl.handle.net/123456789/3432

Norton BW. 1982. Differences between species in forage quality. In: Hacker JB, ed. Nutritional limits to animal production from pastures. Commonwealth Agricultural Bureaux, Farnham Royal, UK. p. 89–110.

Reed JD; Goe MR. 1989. Estimating the nutritive value of cereal crop residues: Implications for developing feeding standards for draught animals. ILCA Bulletin No. 4. ILCA, Addis Ababa, Ethiopia. hdl.handle.net/10568/4610

SAS (Statistical Analysis System). 2007. Statistical Analysis System software. Version 9.0. SAS Institute Inc., Cary, NC, USA.

Van Soest PJ. 1982. Nutritional ecology of the ruminant. Cornell University Press, Ithaca, NY, USA. jstor.org/stable/10.7591/j.ctv5rf668

Van Soest PJ. 1985. Analysis of forages and fibrous foods. Cornell University Press, Ithaca, NY, USA.

Yiberkew N; Mekuriaw Y; Asmare B. 2020. Effects of fertilizer types and plant spacings on plant morphology, biomass yield and chemical composition of *Brachiaria* hybrid Mulato II grass grown in lowlands of Northwest Ethiopia. Scientific Papers: Animal Science and Biotechnologies 53(1):20-35. bit.ly/2YzdD0Z

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