

Effect of Different Levels of Inorganic Nitrogen Fertilizer on Biomass, Seed Yield and Crude Protein Content of Rhodes Grass

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Abstract

The experiment was conducted on-station at Adami Tulu Agricultural Research Center and Negele Arsi (FTC) sites with objective to assess the effect of different levels of inorganic nitrogen (N)-fertilizer on forage biomass, seed yield and crude protein (CP) performances of Rhodes grass. Different levels of inorganic N fertilizers were used as treatments. Accordingly a total of five treatments; Rhodes without fertilizer (T1), 23kg/ha of inorganic N-fertilizer (T2), 46 kg/ha of inorganic N-fertilizer (T3), 69kg/ha of inorganic N-fertilizer (T4) and 92kg/ha of inorganic N-fertilizer (T5) were evaluated in Randomized Complete Block Design (RCBD) with three replications. The result indicated that the highest biomass, seed yield and CP content were obtained from the treatments fertilized with inorganic N-fertilizers significantly ($p < 0.05$) higher compared to the control treatment. The yield and CP contents increased with the increment of the rate of inorganic fertilizers. However, treatments with higher level of fertilizer application didn't produce significance yield and CP differences as compared to the lower level of fertilizer application. This clearly showed that applying fertilizers above the minimum levels (23kg/ha N) didn't produce significantly higher yield and CP in this experiment. The lower yield and CP performance of the control/without fertilizer treatment showed that the experimental soil have not had enough nutrients to sustain optimal performance of Rhodes grass. Based on economic analysis results, the highest marginal rate of returns of 1.23 and 13.18 were produced for forage biomass and seed yield production, respectively, using inorganic N-fertilizer at the rate of 23kg/ha. It indicated that this rate was the most economical among others for herbage biomass and seed yield production of Rhodes grass. Therefore, the optimum inorganic N fertilizer rate for small scale farmers of the study area with low cost of production and higher benefits was at a rate of 23 kg/ha.

Keywords: Biomass yield, Nitrogen fertilizer, Seed yield, Rhodes grass

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Introduction

Livestock contribute significantly to food production directly *via* the provision of high value animal products, and indirectly by supporting crop production through draught power and manure. Moreover, they are important sources of income and store of wealth for smallholder farmers, thereby providing access to food. Despite enormous contribution of livestock to the livelihood of farmers and pastoralists, they are facing multifaceted problems, among which the major one is poor quantity and quality feed supply (Manaye *et al.*, 2009). The major feed resources, natural pasture and crop residues, have low CP and voluntary intake. The area and productivity of grazing lands have greatly declined mainly due to expansion of cropping and consequent disappearance of valuable species, spread of unpalatable species and land degradation which are associated with overstocking and overgrazing (Ayana 2014) owing to congested grazing areas.

Thus, to solve the feed shortage and increase livestock production and productivity, it is necessary to promote the production of high biomass and quality of improved forages suitable to the environmental condition. Improved forage grasses are as one of the most important feed sources for grazing animals. Among forage grass species adapted and recommended so far for mid rift valley of Oromia, Rhodes grass (*Chloris gayana*) is found to be the best performed forage grass (Dawit *et al.*, 2017). Rhodes grass is suitable to tropical and subtropical areas with rainfall ranging from 600- 1600mm per annum when grown on pastureland. It is grown in a wide range of soils; from clays to sandy loam (Valenzuela and Smith, 2002).

Nitrogen fertilizer is one of the most important fertilizers for encouraging grass growth and has great influence on growth and development of seed crops. Rhodes grass responds well to nitrogen fertilizer and the use of fertilizer are found to be important for improving the performances of the grasses (DeBona and Monteiro, 2010, Ahmed and Yassin 2013). Cowan *et al.* (1995) also stated that the increases in pasture yield of Rhodes grass are at a maximum when nitrogen applied to pastures. Herbage yield of Rhodes grass under mid rift valley condition is 5.2 ton DM/ha (ATARC annual report unpublished). This grass can yield up to 15t/ha with the application of nitrogen fertilizer (Getnet *et al.* 2003).

However, there is lack of information on the response of performance of Rhodes grass to inorganic nitrogen fertilizer application. Moreover, the optimum fertilizer rate that can maximize yield and quality of this grass species has not been established under conditions of the mid rift valley of Oromia. Hence, the study was initiated to assess the effect of different levels of inorganic N-fertilizer on agronomic, yield and quality performances of *Chloris gayana* in mid rift valley of Oromia.

Materials and methods

Study area

The experiment was conducted on-station at Adami Tulu and Negele Arsi FTC sites for three consecutive years (2016-2018 E.C. Adami Tulu and Negele Arsi districts are located in the mid rift valley of Oromia, at about 167 and 225km, respectively, south of Addis Ababa on the way to Hawasa. Adami Tulu research center lies at latitude of 7°9'N and 38°7'E longitude. Its altitude is about 1650 meters above sea level (m.a.s.l). It has an average annual rainfall of 727.1mm, whereas the average annual minimum and maximum temperatures of the area during the study period were 11.8°C and 28.3°C, respectively (ATARC metrology data, 2015 - 2017). Negele Arsi district is located at 38° 25' E to 38° 54' E longitude and 07° 09' to 07° 41' N latitude. It has borderlines with Southern Nations, Nationalities and Peoples Regional State (CSA, 2017/18). Negele Arsi district is grouped into three climatic zones based on altitude. These are low, mid and high altitude ranging from 1500- 3070 masl. It has a bimodal rainfall pattern with a short rainy season from March to May and the main rainy season from late June to September. The dry season in the area is mostly from October to February. The mean annual rainfall of the district is 825mm while the annual temperature varies within a range of 16 and 25 °C (CSA, 2017/18).

Experimental treatments and design

Adapted Rhodes grass (*Chloris gayana* Cv. Masaba) was established on a well prepared seedbed using a recommended seeding rate of 15kg/ ha. Different rates of inorganic N-fertilizers were used in the experiment. A total of five treatments, namely, Rhodes without fertilizer (T1), 23kg/ha of inorganic N-fertilizer (T2), 46 kg/ha of inorganic N fertilizer (T3), 69kg/ha of inorganic N fertilizer (T4) and 92kg/ha of inorganic N fertilizer (T5) were used. Treatments arrangements were done based on the recommended inorganic N-fertilizer for Rhodes grass production by different authors (ESGPIP 2008, Getnet *et al.* 2003). The treatments were laid out in RCBD with three replications. Nitrogen fertilizer was splitted into two so that one half was applied at planting and the balance at tillering. Phosphorous fertilizer was applied at the rate of 46kg P₂O₅/ha to all inorganic nitrogen source (UREA) plots.

All necessary data including planting date, days to 50% flowering, plant height, total forage biomass, dry matter and seed yield were recorded. Forage yield was estimated by harvesting the grasses at 50% flowering stage, which is the recommended harvesting stage for perennial grasses to compromise herbage yield and quality. The mature inflorescences were harvested 10-15cm below the panicle; then sun dried, piled for few days and manually threshed and cleaned to estimate seed yields. Herbage samples were dried to constant weight using forced air-drying oven to determine the dry matter using methods described by AOAC (2000). Total nitrogen was determined following Kjeldahl procedure as described by Cottenie (1980).

Partial budget analysis

Simple partial budget analysis was employed for economic analysis at different levels of inorganic N fertilizer application for biomass and seed yield. The potential response of the grass towards the added fertilizer and price of fertilizers ultimately determine the economic feasibility of fertilizer application (CIMMYT, 1988). To estimate the total costs, mean prices of Urea and DAP was collected at the time of planting and market price of Rhodes grass herbage and seed were also taken at harvest. The economic analysis was based on the formula developed by CIMMYT (1988) and given as follows:

Gross average biomass and seed yield (kg/ha⁻¹) (AvY): is an average yield of each treatment.

Adjusted yield (AjY): is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers. $AjY = AvY * (1-0.1)$

Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the grass when they sale it as adjusted yield. $GFB = AjY * \text{field/farm gate price for the grass}$

Total cost: is the cost of UREA and DAP were considered. Their prices was based on the price during experimental periods. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding and harvesting were assumed to remain the same or were insignificant among treatments.

Net benefit (NB): was calculated by subtracting the total costs from gross field benefits for each treatment. $NB = GFB - \text{total cost}$

Marginal return (MR): is the measure of increasing in return by increasing input

Marginal rate of return (MRR %): was calculated by dividing change in net benefit by change in cost.

$$MRR = \frac{\Delta NB}{\Delta TC}$$

According to CIMMYT (1988), the minimum acceptable marginal rate of return (MRR) should be 1.0. If both net income and variable costs increase, the rate of return should be looked at, the greater increase in net income and the higher rate of return, the more economically an alternative technology is, hence, the new technology should be accepted only if its rate of return is higher than 1.0.

Statistical analysis

The collected agronomic, herbage DM and seed yield data were subjected to analysis of variance using the SAS statistical procedures. Means were separated using least significant difference (LSD) at 5% significant level.

Result and Discussions

The results of agronomic performance of Rhodes grass tested for different levels of N- fertilizers are presented in table 1. The result indicated that different levels of inorganic N-fertilizer were significantly ($p < 0.05$) increased plant height of Rhodes grass. The longest mean plant height (90.38 cm) was recorded from treatment with N-fertilizer of 69kg/ha while the shortest (73.98cm) plant height was recorded from the control treatment. Different authors have found different results regarding the effect of N- fertilizer on plant height. Brima (2007) and Abdelrahman (2007) stated that mean plant height of Rhodes grass were not significantly affected by different fertilizer levels while Saad (2009) found a significant effect of nitrogen fertilizer on mean plant height. In other researches, increase in nitrogen fertilization significantly increased grass height (Adam, 2004 and Gasim, 2001, Mohammed, 1990).

On the other hand, there was no significant ($p > 0.05$) differences in plot cover and days to 50% flowering among the tested treatments. Data on days to 50% flowering indicated that the different level of N-fertilizer didn't produced significant ($p > 0.05$) variations among the treatments. However, it takes longer mean of days (91.13) at Negele Arsi site to reach 50% flowering stage as compared to Adami Tulu site (70.33) probably due to the agro-ecology differences as hot climate prompted early maturity of the crops at Adami Tulu site.

Table 1. Mean plot cover, plant height and days to 50% flowering of Rhodes grass in response to different levels of inorganic Nitrogen fertilizers

Treatments	Plot cover (%)			Plant height (cm)			Days to 50% flowering		
	Adami Tulu	Negele Arsi	Mean	Adami Tulu	Negele Arsi	Mean	Adami Tulu	Negele Arsi	Mean
Without fertilizer	75.08	80.75	77.92	66.30b	81.66b	73.98b	72.33	90.33	81.83
23 kg/ha	70.00	90.08	80.04	80.80a	87.33ab	84.06a	71.66	91.33	81.50
46 kg/ha	73.75	85.33	79.54	81.33a	92.16a	86.75a	70.66	91.00	80.83
69 kg/ha	87.75	79.33	83.54	91.26a	89.50a	90.38a	67.66	91.33	79.50
92 kg/ha	79.50	87.50	83.50	85.70a	92.00a	88.85a	69.33	90.66	80.0
Mean	77.22	84.60	80.91	81.08	88.53	84.81	70.33	91.13	80.73
CV	13.64	10.21	13.34	9.58	4.68	8.93	3.95	1.85	14.38
LSD (5%)	NS	NS	NS	14.13	7.54	9.0	NS	NS	NS

¹LSD=Least significant difference. CV=Coefficient of variation, NS= Non significant

²Figure having the same letters with in column are not significantly differ, while values followed by different letter (s) are significantly differ

Herbage dry matter, seed yield and CP recorded from application of different inorganic N fertilizer levels are presented in table 2. At both sites, dry matter, seed yield and CP content were significantly ($p < 0.05$) the higher for the N fertilizer applied treatments than the control. The result of the combined sites indicated that the maximum mean dry matter (13.55t/ha) and seed yield (501.28kg/ha) values were recorded from the higher level (92kg/ha) of N fertilizer treatment. On the other hands the highest mean (11.75%) CP value was recorded for the lower rate of N fertilizer treatment. The control treatment performed the least in all parameters. Previous studies also found that Rhodes grass responded well to nitrogen fertilizer (Valenzuela and smith, 2002). The higher yield obtained from fertilized Rhodes grass could be due to the improvement in soil nutrients. On the other hand, the lower yield and CP obtained from control/without fertilizer treatment showed that the experimental soils have not had enough nutrients to sustain optimal performance of Rhodes grass. Hence, the biomass and seed production as well as CP depends on contribution of N which, in turn, is dependent on the amount of organic matter in the soil. Borhan and Hago (2000) also stated that nitrogen plays an important role in plant growth and physiological processes, as it enters all enzymes composition and enhances vegetative growth and yield.

The trend of dry matter and seed yield increment indicates that the yield increased somewhat with the increment of inorganic N fertilizer rates. However, the tested treatments with inorganic N-fertilizers were not significantly different in yield and CP performance among themselves. So, increasing quantities of inorganic N-fertilizer above 23kg/ha didn't significantly increased dry matter, seed yield and CP contents of Rhodes grass. The significant differences were observed between the control (without fertilizer) and treatments with different levels of fertilizer application. These results made evident that the input of N-fertilizer only from the soil does not allow the grasses to express their biological potential. Moreover, the treatments with higher level of fertilizer application didn't produce significant yield and CP differences as compared to the lower levels of fertilizer application. This clearly showed that applying fertilizers above the minimum levels didn't produce significantly higher dry matter yield in

this experiment. The high value of CP content recorded for the fertilizer applied treatments as compared to unfertilized/control treatment could be due to the addition of N from applied inorganic fertilizer.

Generally, the better yield and CP performance were observed at Negele Arsi as compared to Adami Tulu site. The mean DM (13.78t/ha), seed yield (490.59kg/ha) and CP (11.50%) were recorded at Negele Arsi site while at Adami Tulu 11.34t/ha, 405.48kg/ha and 9.01% values, respectively. The Better yield and CP were recorded for the tested treatments at Negele Arsi as compared to Adami Tulu site which could be mainly due to better soil fertility and soil moisture in the former study area. Climatic conditions are one of the factors that determine herbage DM production of the grasses (Debele *et al.*, 2001). Other finding also confirmed that the variation in climatic and soil type of the experimental area and/or their interactions could also result in yield and CP differences of the forage grasses (Diriba *et al.*, 2014).

Table 2. Dry matter, seed yield and crude protein performance of Rhodes grass in response to different levels of inorganic Nitrogen fertilizers

Treatments	DM yield (t/ha)			Seed yield (kg/ha)			Crude Protein (%)		
	Adami Tulu	Negele Arsi	Mean	Adami Tulu	Negele Arsi	Mean	Adami Tulu	Negele Arsi	Mean
Without fertilizer	9.43b	11.56b	10.49b	294.80b	332.96b	313.88b	6.60b	6.80b	6.70b
23 kg/ha	11.41a	13.79a	12.60a	392.68a	502.33a	447.5a	9.95a	13.54a	11.75a
46 kg/ha	11.74a	14.29a	13.02a	422.00a	510.75a	466.39a	10.00a	13.04a	11.52a
69 kg/ha	11.78a	14.49a	13.14a	450.62a	539.37a	495.00a	9.00a	11.63a	10.32a
92 kg/ha	12.34a	14.75a	13.55a	467.33a	535.22a	501.28a	9.51a	12.48a	10.99a
Mean	11.34	13.78	12.56	405.48	490.59	444.81	9.01	11.50	10.25
CV	17.0	15.03	18.42	24.74	14.45	21.45	14.35	14.61	19.68
LSD (5%)	1.84	2.04	1.53	95.59	67.55	63.24	2.35	3.05	2.40

¹LSD=Least significant difference. CV=Coefficient of variation, NS= Non significant

²Figure having the same letters with in column are not significantly differ, while values followed by different letter (s) are significantly differ

Partial Budgeting Analysis

Partial budget analysis result for herbage biomass and seed production of Rhodes grass in response to different N fertilizer levels are presented in table 3 and table 4, respectively. The cost benefit analysis for Rhodes biomass production revealed that the highest total cost (7730 birr/ha) was recorded from the maximum level (92kg/ha) of inorganic N fertilizer while the lowest total cost was from the control (without fertilizer) treatment. On the other hand, the highest (22793.75 birr/ha) net benefit was obtained from the medium level (46kg/ha) of inorganic N fertilizer. However, the highest marginal rate of returns (1.23) was recorded from treatment with 23kg/ha of inorganic N fertilizer while the other N fertilizer rates showed MRR below 1 and negative value. The values of MRR recorded below 1 for the other inorganic N fertilizer rates could be due to the increase in the total input costs and reduction in the revenue from the treatments as compared to the lowest (23kg/ha) of N-fertilizer application level. Hence, the treatment with inorganic N fertilizer rate of 23kg/ha was found to be the best profitable while the other treatments with MRR below would not be considered.

Table 3. Partial budget analysis of different levels of inorganic nitrogen fertilizers for forage biomass production of Rhodes grass

Descriptions	Without fertilizer	23 kg/ha	46 kg/ha	69 kg/ha	92 kg/ha
Gross income (Birr)					
Average forage DM yield (ton/ha)	10.495	12.6	13.015	13.135	13.545
Adjusted forage DM yield (ton/ha)	9.4455	11.34	11.7135	11.8215	12.1905
Sale price of forage (Birr/ton)	2500	2500	2500	2500	2500
Sale revenue of forage (Birr)	23613.75	28350	29283.75	29553.75	30476.25
Input costs (Birr/ha)					
Rhodes seed	3750	3750	3750	3750	3750
UREA (12birr/kg)		600	1200	1800	2400
DAP (15 birr/kg)		1500	1500	1500	1500
Variable costs (transportation and/or preparation)		20	40	60	80
Total input costs	3750	5870	6490	7110	7730
Net benefit (Birr)	19863.75	22480	22793.75	22443.75	22746.3
Change in net benefits between two consecutive treatments		2616.25	313.75	-350	302.5
Change in total variable input costs between two consecutive treatments		2120	620	620	620
Marginal rate of return		1.23	0.51	-0.56	0.48

The cost benefit analysis for Rhodes seed production using different levels of inorganic N fertilizer levels is indicated in table 4. The highest net benefit of 105054 Birr/ha, was recorded from the highest (92kg/ha) inorganic N fertilizer level. However, the marginal rate of returns for the treatments revealed that the highest value (13.18) was recorded from the application of 23kg/ha of N-fertilizer level. The maximum values of MRR recorded from inorganic N-fertilizer at 23kg/ha rates showed the significant contribution of the N-fertilizer rates on the soil fertility improvement for optimum and cost effective Rhodes biomass and seed yield production. Hence, the highest marginal rate of returns produced from 23kg/ha of inorganic N-fertilizer rates for biomass and seed yield production indicated that these rates were the most economical among the other rates for herbage biomass and seed production from Rhodes grass at the study area.

Table 4. Partial budget analysis of different levels of inorganic nitrogen fertilizers for seed production of Rhodes grass

Descriptions	Without fertilizer	23 kg/ha	46 kg/ha	69 kg/ha	92 kg/ha
Gross income (Birr)					
Average seed yield (kg/ha)	313.88	447.515	466.375	494.985	501.26
Adjusted seed yield (kg/ha)	282.492	402.7635	419.7375	445.4865	451.134
Sale price (birr/kg)=250	250	250	250	250	250
Sale revenue (Birr)	70623	100690.88	104934.38	111371.63	112783.5
Input costs (Birr/ha)					
Rhodes seed	3750	3750	3750	3750	3750
UREA (12birr/kg)		600	1200	1800	2400
DAP (15 birr/kg)		1500	1500	1500	1500
Variable costs (transportation and/ or preparation)		20	40	60	80
Total input costs	3750	5870	6490	7110	7730
Net benefit (Birr)	66873	94820.875	98444.375	104261.63	105054
Change in net benefits between two consecutive treatments		27947.875	3623.5	5817.25	791.875
Change in total variable input costs between two consecutive treatments		2120	620	620	620
Marginal rate of return		13.18	5.84	9.38	1.27

Conclusions

The study indicated that all treatments with N fertilizers have produced better dry matter, seed yield and CP content as compared to the non-fertilized (control) treatment. However, the treatments with inorganic N fertilizers were

not significantly different in dry matter and seed yield production among themselves. Hence, applying inorganic N fertilizer above 23kg/ha didn't produce significantly higher dry matter, seed yield and CP content. Economic analysis results also showed that benefits from Rhodes grass can be increased through application of inorganic N-fertilizers. However, the highest marginal rate of returns produced from 23kg/ha inorganic N-fertilizer indicated that this rate is the most economical among the others for herbage biomass and seed production. Hence, it is logical to recommend inorganic N-fertilizer at the rate of 23kg/ha for optimum dry matter and seed yield and CP improvement of Rhodes grass at the study area.

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