

Research Article

Effect of Nitrogen Level on Herbage and Seed Yield of Rhodes Grass (*Chloris gayana*)

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Nitrogen is the most important macronutrient for forage and food crop production. Currently, cultivable lands in Ethiopia undergo a deficiency of this element. Thus, this study was conducted to find an appropriate rate of nitrogen (N) fertilizer for the better agronomic performance of *Chloris gayana* Masaba. The experiment was carried out at Assosa Agricultural Research Center. The experiment was conducted using a randomized complete block design with three replications, and the treatments were five levels of nitrogen fertilizer (0, 23, 46, 69, and 92 kg N/ha). The collected data were analyzed using the general linear model procedure of SAS, and the least significance difference was used for mean separation. Plant height at forage harvesting, dry matter yield, leaf to stem ratio, leaf height, number of leaves per plant, number of tillers, and seed yield were significantly ($p < 0.001$) influenced by the year of planting while nonsignificantly ($p > 0.05$) by nitrogen fertilizer rate and interaction of planting year and fertilizer rate. The mean leaf to stem ratio was significantly ($p < 0.001$) higher in 2017 and 2018 than in the 2019 planting year. However, forage dry matter yield was significantly ($p < 0.001$) higher in 2019, followed by 2018 and 2017 planting years. Mean seed yield was significantly ($p < 0.001$) different among the establishment years and the peak seed yield productivity attained during the third year of harvesting (1st = 2nd < 3rd year of harvesting). Generally, all measured agronomic traits were not significantly responsive to the different fertilizer rates, and in the economic point of view, 0 kg of N/ha is recommended.

1. Introduction

Forage production is gaining more attention in the tropics and the subtropics in both developed and developing countries. New species, varieties, and cultivars of forage and pasture plants have been introduced from areas and countries rich in forage and pasture plants to areas where they are scarce [1]. However, the main feed resources for livestock in Ethiopia are natural pasture and crop residues, which are low in quantity and quality for sustainable animal production [2, 3]. In Ethiopia, crop residues of cereals and pulses account for about 32% of the total feed utilized and ranked second to grazing (37%) [4]. Natural pastures that provide the bulk of ruminant feed in Ethiopia are depleted from time to time, and their average annual productivity does rarely exceed 1.5–2.5 t ha⁻¹ dry matter under the

continuous communal grazing system [5]. Crop residues as other major sources of livestock feed could not meet the nutritional requirements of the animals due mainly to low protein and high fiber contents. Hence, these feeds have to be complemented with cultivated pasture species of high forage yield with reasonable quality if any meaningful production level is to be expected from livestock. The shortage of feed is exacerbated by the increase in human and livestock population and the expansion of cropland, resulting in the decrement of grazing land [6]. In such situations, improved forage options that address yield and nutritive issues are needed to increase livestock productivity. This requires the introduction of high-quality cultivated forage with high yielding ability and adaptability to biotic and abiotic environmental stresses [7–9]. Much important improved forage has been generated by the research systems

over the last years in the country. Among the improved forage crops introduced into Ethiopia, *Chloris gayana* could play an important role in providing a significant amount of yield and quality forage under smallholder farmers and intensive livestock production systems [10]. However, the yield of improved forage species can be low due to management information gaps such as application of fertilizer, irrigation, weeding, optimum spacing, and harvesting days. There is inadequate information on the management practices that influence dry matter yield and nutritive value of *Chloris gayana* when grown with appropriate nitrogen fertilizer and stage of harvesting. *Chloris gayana* Masaba species is among the *Chloris gayana* species selected for their adaptation and herbage yield in most parts of Ethiopia. Nitrogen fertilization develops stronger cells for photosynthesis [11]. Nitrogen fertilization benefits grasses by the decay of root nodules or mineralization of shed leaves and increases forage dry matter yield, forage quality in terms of crude protein content, voluntary feed intake, and digestibility [12]. Fertilizer application is responsible for the changes in herbage yield [11]. However, the use of fertilizers to improve forage yield is limited [13], and there should be local information to encourage forage growers to use fertilizer in forage cultivation. Tropical grasses drastically reduce in their nutritive value with an advance in the stage of harvesting. Nitrogen fertilization application is predominantly responsible for the changes in nutritive value [14]. Nevertheless, information regarding the effect of fertilizer on biomass yield and nutritive value of *Chloris gayana* Masaba adapted to Ethiopia is lacking. One means of enhancing the yield and quality of forage is through fertilizer application. Thus, the present study was designed to evaluate the effect of nitrogen fertilizer on herbage and seed yield of Rhodes grass (*Chloris gayana* Masaba) grown rain-fed in Western Ethiopia.

2. Materials and Methods

2.1. Study Area. The study was conducted at Assosa Agricultural Research Center which is located in Benshangul-Gumuz Regional State, Western Ethiopia. Assosa is located within 10°30'N latitude and 034°20'E longitude and an altitude of 1576 meters above sea level. The pattern of rain is unimodal with a mean annual rainfall of 1275 mm. The minimum temperature varies between 14°C and 20°C, and the maximum temperature ranges from 25°C to 39°C. The soil type is reddish-brown nitisols [15].

2.2. Experimental Design and Materials Used. The experiment was conducted with five levels of nitrogen fertilizer rate (0, 23, 46, 69, and 92 kg N/ha). The N fertilizer was applied when the grass was sown by drilling on the rows depending on the fertilizer treatment. Field trials were arranged in a randomized complete block design with three replications. The spacing between replication and plots was 2 and 1.5 m, respectively. The plot size was 3 m * 4 m (12 m²). There was one year of establishment, followed by several years where the grass was harvested. The samples for dry matter and seed

yield determination were harvested from four angles of each plot. During sampling at 10% flowering for dry matter yield estimation, a 1 m* 1 m quadrat was randomly thrown at the two diagonal angles of each plot and harvested by machete from each plot, and then, it was weighed for its fresh weight right in the field. However, the other two diagonal angles of each plot were harvested at physiological maturity for seed yield estimation. Herbage samples were dried to constant weight using a forced air-drying oven to determine the dry matter percentage. Forage yield was estimated by harvesting the grasses at the stage of 10% flowering. The dry matter yield was calculated after drying a sample of 500 g green forage in an oven at 650 C for 72 hours [16] in Assosa Agricultural Research Center which was converted into hectares. The plant height was measured by averaging the natural standing height of six plants per plot. The main branch number was an average of primary branches on the stem of six plants per plot. The mature inflorescences (three weeks after full flowering) were harvested 10–15 cm below the panicle and then sun-dried, piled for a few days, and manually threshed and cleaned to estimate seed yield. Seed yield data were taken after proper drying by sensitive balance.

2.3. Data Analysis. The data collected on agronomic traits were subjected to analysis of variance by using the general linear model (GLM) procedure in R software, and mean separation was done using the LSD test at 5% probability level. The effects of nitrogen fertilizer application rates on morphological characteristics, dry matter, and seed yield were determined using the following model: $Y_{ijk} = \mu + R_i + N_k + e_{ik}$, where Y_{ijk} = dependent variables, μ overall mean, $R_i = i$ th replication of nitrogen fertilizer application rate, $N_k = (k$ th 1–4) level of nitrogen fertilizer application rate, and e_{ik} = error component for plot and interaction.

3. Results and Discussion

3.1. Effects of Establishment Years and Interaction on the Performance of *Chloris gayana*. A combined analysis of variance for measured agronomic traits of *Chloris gayana* Masaba at different levels of nitrogen fertilizer rate is presented in Table 1. The results of this study revealed that all measured agronomic traits were significantly ($P < 0.001$) different among the establishment years, and this might be due to climatic variations between the establishment years. The level of nitrogen fertilizer rate and the interaction of establishment years and nitrogen fertilizer rate were not significantly ($P > 0.05$) influencing all measured agronomic traits of *Chloris gayana* Masaba.

As indicated in Figure 1, forage dry matter yield, the number of branches per plant, and the number of tillers were maintained/increased throughout the establishment years and this implies the growth performance of *Chloris gayana* during the first establishment year is very slow even under the regime of fertilizer application. This might be the nutrient supply in the first year of the establishment may

TABLE 1: Effects of years of planting and interaction on measured agronomic traits of *Chloris gayana*.

S. no.	N levels (N)	Years (Y)	Nxy	Mean	CV
(1) Plant height (cm)	ns	***	ns	86.38	15.56
(2) Forage DM yield (t/ha)	ns	***	ns	4.70	28.47
(3) Leaf to stem ratio	ns	***	ns	0.71	21.25
(4) Leaf height (cm)	ns	***	ns	32.85	20.08
(5) No. of branches per plant	ns	***	ns	8.20	15.41
(6) Number of tillers	ns	***	ns	19.82	13.88
(7) Seed yield	ns	***	ns	276.90	35.55

*** $P < 0.001$

enhance more root development than vegetative biomass growth in perennial grasses. This in turn would determine the subsequent herbage or seed productivity of the species in the following production seasons. Consequently, seed yield and forage dry matter yield were shown to increase from the first year of establishment to the third year. Leaf to stem ratio was higher for the second year of establishment than the third year of establishment, and this might be because a higher mean leaf height was recorded during the second year of establishment than the third year of establishment. The number of tillers per plant showed an increment during the first year of establishment to the third year of establishment, and this might be due to the variation in climate among the establishment year. Increased tillering is probably an adaptive feature to tolerate frequent defoliation by reestablishing the lost photosynthetic areas and maintaining the basal area. In the year after establishment, rhizomes had spread in the plot increasing tiller density. High tiller production not only indicates stable productivity [17] but also is linked to better persistence after periods of unfavorable environmental conditions [18]. Similarly, the number of leaves per plant was increased with the year of establishment, and this might be due to the number of leaves per plant and the number of tillers positively correlated. Forage dry matter yield was also increased with the establishment year opposite to the leaf to stem ratio, and this might be because more stem forages are higher in dry matter yield (leaf to stem ratio negatively correlated with forage dry matter yield).

3.2. Leaf to Stem Ratio. The mean leaf to stem ratio of *Chloris gayana* Masaba at different levels of nitrogen fertilizer rate is presented in Table 2. Leaf to stem ratio was not significantly ($P > 0.05$) different among the levels of nitrogen fertilizer rate across the establishment years. The result of the combined analysis revealed that the leaf to stem ratio was not significantly influenced by the level of nitrogen fertilizer rate. This observation is in accordance with those obtained in [1, 19], which reported that the leaf to stem ratio of *Chloris gayana* was not influenced by nitrogen and NPK fertilizer rate, respectively. This might be due to the fertilizer applied one dose. The mean leaf to stem ratio was significantly ($P > 0.001$) decreased from the first year of establishment to the third year of establishment, and this might be because a decrease in a leaf to stem ratio with the longer year of establishment is a function of longer periods of physiological growth with reduced defoliation frequency

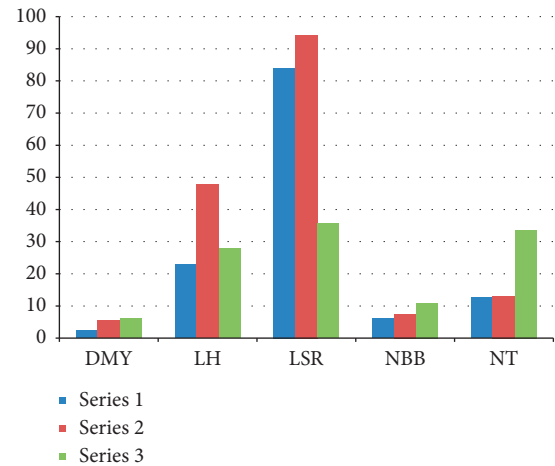


FIGURE 1: Agronomic traits over three years. DMY = dry matter yield (t/ha); LH = leaf height (cm); LSR = leaf to stem ratio; NBB = number of leaves per plant; NT = number of tillers; series 1 = planting year 1; series 2 = harvesting year 2; series 3 = harvesting year 3.

stimulating stem growth at the expense of leaf production [20]. The leaf to stem ratio has significant implications on the nutritive quality of the grass as leaves contain higher levels of nutrients and less fiber than stems. The results indicated that the LSR is an important factor affecting diet selection, quality, and intake of forage [21]. The LSR is associated with the high nutritive value of the forage because the leaf is generally of a higher nutritive value [22], and the performance of animals is closely related to the number of leaves in the diet. This observation is in accordance with those obtained in [1, 19].

3.3. Forage Dry Matter Yield. The mean forage dry matter yield of *Chloris gayana* at different levels of nitrogen fertilizer rate is indicated in Table 3. Forage dry matter yield was not significantly ($P > 0.05$) influenced by nitrogen fertilizer rate difference across the year of establishment and this might be due to the early (during sowing) application of nitrogen fertilizer to the plants in one dose; therefore, the growing plants did not use the fertilizer efficiently in the late of their growth when they were at an age of 30–45 days. Although the applied nitrogen in one dose might be lost by leaching, this makes the result nonsignificant. The authors in [23] showed that a split application of nitrogen is superior to a large single application in producing a yield of warm-season grasses. Similar results were reported in [24, 25]

TABLE 2: Mean leaf to stem ratio of *Chloris gayana* grass in response to different N fertilizer levels.

Treatments	Year			Combined over years
	2017	2018	2019	
0 kg N ha ⁻¹	0.83	1.07	0.42	0.77
23 kg N ha ⁻¹	0.90	0.91	0.39	0.71
46 kg N ha ⁻¹	0.87	0.87	0.34	0.69
69 kg N ha ⁻¹	0.87	0.91	0.33	0.70
92 kg N ha ⁻¹	0.79	0.95	0.31	0.69
Mean	0.85 ^a	0.94 ^a	0.36 ^b	0.71
CV	14.61	22.84	31.06	19.65
Significance level	ns	ns		ns

Mean with the same letter are not statistically nonsignificant, but means with different letters are statistically different.

TABLE 3: Mean forage DM yield (t ha⁻¹) of *Chloris gayana* grass in response to different N fertilizer levels.

Treatments	Year			Combined over years
	2017	2018	2019	
0 kg N ha ⁻¹	1.96	4.65	7.46	4.69
23 kg N ha ⁻¹	1.59	6.85	6.82	5.32
46 kg N ha ⁻¹	2.88	5.23	5.74	4.62
69 kg N ha ⁻¹	1.98	6.12	5.68	4.59
92 kg N ha ⁻¹	3.04	4.71	5.09	4.28
Mean	2.38 ^b	5.51 ^a	6.17 ^a	4.70
CV	33.56	25.53	34.27	37.42
Significance level	ns	ns	ns	ns

Mean with the same letter are not statistically nonsignificant, but means with different letters are statistically different.

about the application of N to Rhodes grass. This result implies that the experimental soil had enough nutrients to sustain optimal performance of *Chloris gayana* grass either the N₂ applied at 100 kg ha⁻¹ or not applied (without N₂ application). Also, the nonsignificant result might be contributed to the low rate of applied nitrogen across the treatments. The results of the combined analysis also indicated that the mean forage dry matter yield was not significantly ($P > 0.05$) different among the different nitrogen fertilizer rates. In agreement with this study, Brima [1] reported that the forage dry matter yield of *Chloris gayana* is not influenced by the application of NPK fertilizer. The year of the establishment was significantly ($P < 0.001$) affecting the mean forage dry matter yield, and this might be attributed to the variation in climatic conditions between the years of establishment. *Chloris gayana* produces peak forage dry matter yield during the third year of establishment, and this might be due to fertilizer application, which enhances the production of more tillers and the number of branches per plant during the third year. This result is in agreement with the finding in [26] who reported that Napier grass could produce a peak number of tillers during the third year of establishment and that fertilizer application enhances the production of more tillers.

3.4. Seed Yield. The mean seed yield of *Chloris gayana* in response to different N fertilizer levels is presented in Table 4. Mean seed yield was not significantly ($P > 0.05$)

TABLE 4: Mean seed yield (kg ha⁻¹) of *Chloris gayana* in response to different N fertilizer levels.

Treatments	Year			Combined over years
	2017	2018	2019	
0 kg N ha ⁻¹	124.13	199.17	433.20	252.17
23 kg N ha ⁻¹	187.00	224.10	376.27	256.24
46 kg N ha ⁻¹	155.40	238.90	443.00	279.10
69 kg N ha ⁻¹	167.13	248.20	440.43	285.26
92 kg N ha ⁻¹	184.00	195.40	555.77	311.72
Mean	161.86 ^b	221.15 ^b	449.73 ^a	449.73
CV	29.96	18.50	35.95	34.27
Significance level	ns	ns	ns	ns

Mean with the same letter are not statistically nonsignificant, but means with different letters are statistically different.

affected by the variation in nitrogen fertilizer rate, and this might be due to the experimental unit on which the experiment was carried out covered by legume forage. This implies the nitrogen content of the soil is improved, and the application of nitrogen fertilizer cannot respond to the measured agronomic traits. Additionally, the nitrogen fertilizer is applied one time to plants in one dose (only during sowing), and this makes plants not get efficient fertilizer at the postestablishment. This implies the herbage and decrease in seed yield of *Chloris gayana*. In agreement with this study, Assefa et al. [27] reported that the time of fertilizer application has an overriding effect in addition to the rate of application in postestablishment crops. Even though the applied nitrogen might be lost by leaching, this makes the result nonsignificant. Similarly, Bogdan [28] reported that nitrogen applied as urea is expected to be lost through leaching and volatilization. The year of the establishment significantly ($P < 0.001$) influenced seed yield of *Chloris gayana*, and this might be due to residual effects of applied nitrogen fertilizer. Seed yield of *Chloris gayana* showed peak productivity during the third year of establishment. This indicates the residual fertilizer value of nitrogen in improving crop response towards the later stage of establishment. In general, the overall mean seed yield of Rhodes grass in this experiment ranged from 161.86 kg ha⁻¹ to 449.73 kg ha⁻¹; in taking climatic and seasonal variations into account, this yield range is in agreement with [28] which stated that, under tropical conditions, *Chloris gayana* produces two crops of seed per year and seed yield ranges from 65 to 650 kg ha⁻¹ year⁻¹.

4. Conclusion

The overall measured agronomic traits were nonsignificant in response to the different nitrogen fertilizer rates. Therefore, in the economic point of view, 0 kg N/ha is recommended for *Chloris gayana* Masaba in the study area. However, there is a need to evaluate the productivity of *Chloris gayana* under split application of nitrogen fertilizer since the time of application has an overriding effect in addition to the rate of application in postestablishment crops.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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