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Effects of Spacing and Nitrogen Fertilizer on Growth and Biomass Yield of Mezrut Grass (*Echinochloa* spp.) under Rain Fed Condition in Western Tigray, Northern Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. Author GG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors GM and SM managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Mezrut grass (*Echinochloa* spp.), which was one of the locally available grass, was released by Humera Agricultural Research Center (HuARC) by intended to contribute paramount role in addressing feed shortage of the area, but yet it is not documented with its appropriate agronomic practices such as nitrogen fertilizer and spacing. This study was conducted at Humera, Kebabo, Banat, Zerbabit and Ruwasa, western zone of Tigray, northern Ethiopia in 2018 under rain fed condition to determine effect of spacing and nitrogen fertilizer on growth and biomass yield of Mezrut grass (*Echinochloa* spp.). The experiment was arranged in a split plot design with six nitrogen fertilizer levels (0, 11.5, 23.0, 34.5, 46.0 and 57.5 $kgNha^{-1}$) applied in the form of urea and four spacing (40, 60, 80 and 100 cm), with *Echinochloa* spp. as a test crop. Data were recorded on dry matter yield (DMY), 50% flowering date, plant height and number of tillers at harvest. Statistical significant difference ($p<0.05$) due to nitrogen fertilizer was observed on DMY, 50% flowering date

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and plant height at harvest. Similarly, the study also revealed that spacing had significant (p<0.001) effect on DMY and plant height at harvest. Relatively higher DMY and plant height at harvest were obtained from 23.0, 34.5, 46.0 and 57.5 kg Nha^{-1} as compared with the other treatments set up. Moreover, higher and lower values of DMY and plant height at harvest were obtained from 40 and 80cm spacing, respectively. The study suggested that application of 23.0 $kgNha^{-1}$ and 40 cm spacing improved biomass yield and plant height at harvest of Mezrut grass (*Echinochloa* spp.) under rain fed condition and recommended to be implemented. Therefore, application of 23.0 $kgNha^{-1}$ and 40cm spacing to boost biomass yield and plant height of *Echinochloa* spp. should be demonstrated and popularized in the study area and other similar agro ecologies of the country.

Keywords: Dry matter yield; Echinochloa spp.; nitrogen fertilizer; spacing.

1. INTRODUCTION

Because of rapid human population and income growth, together with urbanization, the demand for livestock products is increasing throughout the world [1,2]. World meat production and consumption have been increased, according to [3], in particular by rising living standards in developing countries. People in developed countries currently consume about 3 to 4 times as much meat and fish, and 5 to 6 times as much milk products per capita as in developing Asia and Africa. Meat, milk, and fish consumption per capita has barely grown in the developed countries as a whole over the past 20 years [4]. According to Christopher, et al. [4], yet poor people everywhere clearly desire to eat more animal protein products as their incomes rise above poverty level and as they become urbanized. However, due to health problems, poor management and low genetic potential and feed shortages, animal productivity is still too low, as a result, the current demand cannot be fulfilled.

Feed both in terms of quantity and quality is a major bottleneck for livestock production in Ethiopia [5,6]. Feed resources can be classified as natural pasture, crop residue, agro-industrial byproducts [7], and improved forage of which the first two contribute the largest share [6]. Moreover, crop residue is the major livestock feed in Oromia, Amhara and Tigray, whereas in the South Nations, Nationalities and Peoples (SNNP) region grazing lands and crop residues are the major sources of livestock feed [5]. Besides, the overall contribution of crop residues exceeds 50% of the livestock feeds currently used by smallholder farmers [8]. However, crop residues are fibrous byproducts and their feeding value are limited by their poor voluntary intake, low digestibility and low nitrogen, energy, mineral and vitamin contents [9,6]. Moreover, with the rapid increase of human population and increasing demand for food, grazing lands are steadily shrinking by being converted to arable lands [9], and are restricted to areas that have little value [5,6].

Thus, using indigenous forage grasses such as Mezrut grass (*Echinochloa* spp) as feed source is one option to address this situation. *Echinochloa* spp. is one of the promising grass varieties intended to play a key role in addressing feed shortage in Western zone of Tigray, Northern Ethiopia. It was registered as best feed resources of the area in 2017 Gregorian calendar (G.C.) and was recommended for relatively low to high moisture areas of lowland Tigray and other similar Ethiopian agro ecologies. Being native to the area, drought resistant, having 13.88% crude protein (CP) and 22.33 $tonha^{-1}$ of forage yield makes it an important grass for the area [10,11]. there is no evidence, however, regarding the appropriate agronomic practice like spacing between row and optimum rate of N fertilizer on growth and biomass yield of Mezrut grass (*Echinochloa* spp.) in the study area and other similar Ethiopian agro ecologies. Therefore, the study was designed with the aim of determining effects of spacing and nitrogen fertilizer on growth and biomass yield of Mezrut grass (*Echinochloa* spp.).

2. MATERIALS AND METHODS

2.1 Description of the Study Area

This study was conducted at Kafta Humera (Humera, Zerbabit, Ruwassa and Banat sites) and Tsegede (Kebabo site) Districts of Western Zone of Tigray (WZT), Northern Ethiopia (Fig. 1). Western Zone of Tigray is located at 570 and 991 km far from Mekelle and Addis Ababa, respectively [12]. It lies at 13º42′ to 14º28′ north latitude and 36º23′ to 37º31′ east longitude [13] and share borders with Tahtay Adiyabo Woreda, Sudan, Amhara region and Eritrea in the East, West, South and North, respectively. Similarly, its altitude ranges from 500-3000 m.a.s.l for Humera and Ketema Nugus, respectively. Moreover, it consists of three agro-ecological zones (lowland, midland and highland) in which *kola* (lowland), *weynadegga* (midland) and *dega* (highland) accounts for 75%, 15.7% and 9.3%, respectively of the land coverage. Its annual rainfall ranges from 600 to 1800 mm with maximum and minimum temperatures of 45 and 12ºC, respectively [12].

Moreover, WZT covers a total area of 1.5 million hectares, of which grazing lands cover 116921.88 hectare (10.4%) [12,11]. Likewise, livestock sector is the predominant economic activity of the area in which 95% of the total population engaged directly or indirectly on it [13]. Local *Arado* (in both high land and mid land areas) and *Begait* cattle (in lowland areas) are the main cattle breeds reared in the study area. Similarly, major livestock feed resources in the study area includes natural pasture, crop residues, woody browses (shrubs, bush and tree) and others such as stubble, hay and tree foliages, of which natural pasture and followed by crop residues are the main ones [14].

2.2 Plot Preparation, Planting Method and Fertilizer Application

Mezrut grass (*Echinochloa* spp.) was planted in a well prepared plot in row planting method at the beginning of July, 2018. The plot was cleared by manpower and ploughed by oxen two times followed by leveling before planting to control weeds and to be convenient in germination. Each plot had a size of 2.5 m length and 5 m width with 1.5 and 1.0 m spacings between each block and plot, respectively. The grass was planted in drilling method at a depth of about 2.5 cm and lightly covered with soil to ensure adequate emergence. Moreover, urea fertilizer was applied after 15 and 30 days of emergence by divided in to two equal amounts by placing near root slips depending on the treatments. Besides, the fertilizer application was done at one day for each period. it was good rain fall distribution during the period when the experiment was

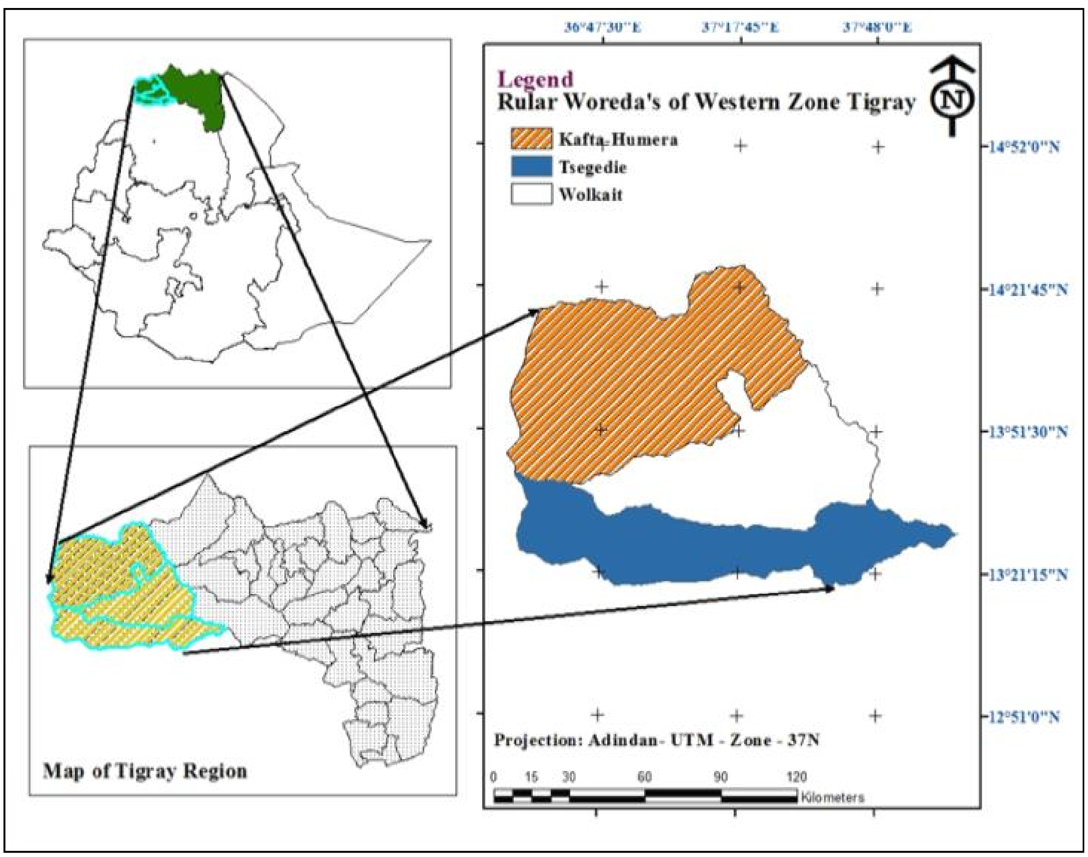

Fig. 1. Location map of the study area, Western Zone of Tigray region, Northern Ethiopia [15]

conducted. Similarly, prior to planting and after harvesting soil sample was taken randomly per replication at each corner and center of each replication using soil sampling auger.

2.3 Experimental Design and Treatments

For this study Split Plot Design (SPD) with three replications was used. The treatments were six nitrogen fertilizer levels (0, 11.5, 23.0, 34.5, 46.0 and 57.5 kg Nha^{-1}) were applied in the form of urea and four spacing (40, 60, 80 and 100cm), Mezrut as test grass. Mezrut grass was one of the locally available, herbaceous, perennial, palatable grass and together with high tillering ability and regeneration capacity. It can be used as cut and carry system, direct grazing, hay and silage. Nitrogen fertilizer rates and spacing were used as main-plot and sub-plot treatments, respectively. Two separate randomization process were used, one for main plot and another for the subplot. In each replication, main plot treatments were first randomly assigned to the main plots followed by a random assignment of the sub plot treatments within each main plot.

2.4 Methods of Data Collection

Data were recorded from the sample plants during the course of experiment. Three plants were selected from each of the unit plot for the collection of data. The plants in the outer rows and the extreme end of the middle rows were excluded from the random selection to avoid the border effect. Moreover, fresh biomass yield was taken by harvesting the middle rows at 50% flowering stage. Consequently, dry matter yield was calculated after drying a sub-sample of green forage in an oven at 105ºC for 24 hours in Humera Agricultural Research Center which was converted in to hectare.

2.5 Data Analysis

Data were analyzed by Genstat Eighteenth Edition and subjected to analysis of variance (ANOVA). Moreover, means were separated by Fisher's unprotected least significant difference test at 5% probability level.

3. RESULTS AND DISCUSSION

3.1 Effect of Nitrogen Fertilizer on Dry Matter Yield (DMY)

Based on the overall mean result, significant difference on DMY was observed due to nitrogen fertilizer and higher yield was obtained from 23.0, 46.0 and 57.5 kg N ha^{-1} as compared with zero level of fertilizer, but there is no statistical significant difference among 11.5, 23.0, 34.5, 46.0 and 57.5 kg N ha^{-1} (Table 1). The lower DMY at Humera as compared with the other locations could be due to Humera was over utilized for crop production for many years as compared to the others. The increase in yield of forage under nitrogen application can be

Table 1. Means ± SE of dry matter yield (tonha^{-1}) of *Echinochloa* spp. at five locations

LF (kgNha^{-1})	Locations					Over all mean
	Banat	Humera	Kebabo	Ruwasa	Zerbabit	
0	16.08^{ab}	9.653^{b}	8.80^{c}	5.903^{c}	7.141^{b}	9.95^{b}
11.5	15.36^{abc}	9.96^{b}	9.97^{bc}	8.190^{b}	10.067^{a}	10.71^{ab}
23.0	16.49^{a}	8.38^{c}	12.13^{a}	9.852^{ab}	10.574^{a}	11.49^{a}
34.5	14.33^{bc}	9.37^{bc}	10.12^{bc}	10.911^{a}	9.194^{a}	10.79^{ab}
46.0	13.36^{c}	9.46^{bc}	12.05^{a}	10.903^{a}	10.258^{a}	11.21^{a}
57.5	14.25^{bc}	11.93^{a}	10.86^{ab}	11.137^{a}	9.743^{a}	11.58^{a}
SE	0.912	0.560	1.341	0.893	0.743	0.468
CV (%)	7.5	7.8	6.9	11.5	9.6	5.2
P-value	0.044	0.002	0.002	<.001	0.010	0.049
IRS(cm)						
40	16.42^{a}	12.22^{a}	12.94^{a}	9.852	11.256^{a}	12.54^{a}
60	16.02^{a}	9.88^{b}	10.56^{b}	10.000	10.679^{a}	11.43^{b}
80	14.48^{b}	10.07^{b}	9.11^{c}	9.259	9.236^{b}	10.43^{bc}
100	13.00^{c}	8.44^{c}	10.0^{bc}	8.819	6.815^{c}	9.42^{c}
SE	0.965	0.677	0.965	0.892	0.946	0.531
CV (%)	5.5	7.4	4.8	7.7	5.7	3.5
P-value	<.001	<.001	<.001	0.308	<.001	<.001

Means with the same letter in a column are not significantly different; LF: Level of fertilizer; IRS: Inter-row spacing; CV: Coefficients of variation; SE: Standard errors of the mean attributed to the positive effect of nitrogen on all the growth parameters investigated in the current study.

3.2 Effect of Spacing on DMY

Higher and lower DMY was obtained from the narrow (40cm) and wide (100 cm) spacing, respectively and intermediate for the others (Table 1). Besides, as shown from the result, DMY decreased as spacing increase. This could be due to better plant height at harvest and high population density in the narrow spacing groups. On the contrary, the lower DMY at the higher inter-row spacing could be due to lower plant height and population density. The current finding was in line with that of Sumran, et al. [16] and [17]. But, in contrary with that of Genet, et al. [18] and Worku, et al. [19] who reported that DMY was not affected by plant spacing and was increased with spacing, respectively.

3.3 Effect of Nitrogen Fertilizer on 50% Flowering Date

There was significant difference between the treatment groups with and without fertilizer, but absence of significant difference was observed among the treatment groups with fertilizer (Table 2). The treatment groups with fertilizer reached 50% flowering date within short period of time; this could be due to the fact that nitrogen application accelerated the time to reach 50% tasseling and is comparable with the finding of Mohamed [20].

3.4 Effect of Nitrogen Fertilizer on Plant Height at Harvest

Higher plant height at harvest was obtained from 57.5 $kgNha^{-1}$as compared with 11.5 and 0 $kgNha^{-1}$, but there was no significant difference among 57.5, 23.0, 34.5, and 46.0 $kgNha^{-1}$ and 11.5 and 0 kg Nha^{-1} (Table 3). The increase in plant height with nitrogen fertilizer can be attributed to the fact that nitrogen promotes plant growth, increases the number and length of the internodes which results in progressive increase in plant height [20].

3.5 Effect of Spacing on Plant Height at Harvest

Higher plant height at harvest was recorded at 40 and lower was at 100 cm and intermediate for the others, and it was observed that plant height at harvest was decreased as spacing increase. This could be due to the fact that narrow spacing increased interplant competition, causing individual plants to grow taller with longer internodes, plus slender, thin and weak stalks due to poor light exposure and hence poor photosynthetic output [21]. The current finding was contradicted with that of Mohamed [20] who

Table 2. Means ± SE of 50% flowering date (days)) of *Echinochloa* spp. at five locations

LF ($kgNha^{-1}$)	Location					Over all mean
	Banat	Humera	Kebabo	Ruwasa	Zerbabit	
0	58.17 ^{a}	65.42^{a}	65.58^{a}	61.58^{a}	59.00^{a}	61.95^{a}
11.5	53.42 ^{bc}	60.50^{b}	60.50^{b}	56.25^{c}	54.75^{b}	57.08^{b}
23.0	53.50 ^{bc}	60.25^{b}	60.42^{b}	56.42 ^{c}	54.50^{b}	57.10^{b}
34.5	53.25 ^{c}	60.50^{b}	60.58^{b}	56.92^{b}	54.33^{b}	57.02^{b}
46.0	53.42 ^{bc}	60.50^{b}	60.58^{b}	56.58^{bc}	54.33^{b}	57.08^{b}
57.5	53.75 ^{b}	60.25 ^{b}	60.33 ^{b}	56.58^{bc}	54.67^{b}	57.12^{b}
SE	0.1900	0.2781	0.2626	0.2194	0.3111	0.113
CV (%)	0.4	0.6	0.5	0.5	0.7	0.2
P-value	<.001	<.001	<.001	<.001	<.001	<.001
IRS(cm)						
40	54.22	61.28	61.39	57.50	55.11	57.90
60	54.17	61.22	61.28	57.22	55.39	57.86
80	54.17	61.06	61.28	57.39	55.33	57.84
100	54.44	61.39	61.33	57.44	55.22	57.97
SE	0.1841	0.1879	0.1689	0.1665	0.2354	0.089
CV (%)	0.2	0.2	0.0	0.2	0.3	0.1
P-value	0.384	0.416	0.857	0.404	0.618	0.513

Means with the same letter in a column are not significantly different; LF: Level of fertilizer; IRS: Inter-row spacing; CV: Coefficients of variation; SE: Standard error of the mean

Table 3. Means ± SE of plant height at harvest (cm) of *Echinochloa* spp. at five locations

LF ($kgNha^{-1}$)	Locations					Over all mean
	Banat	Humera	Kebabo	Ruwasa	Zerbabit	
0	210.7^{b}	117.4^{a}	182.3	145.4^{d}	105.3^{d}	152.2^{c}
11.5	218.7^{ab}	113.6^{a}	184.7	155.5^{c}	122.8^{b}	159.1^{bc}
23.0	210.5^{b}	105.6^{b}	190.1	174.4^{b}	121.0^{bc}	160.3^{ab}
34.5	207.8^{b}	105.7^{b}	184.1	168.0^{b}	136.3^{a}	160.4^{ab}
46.0	224.1^{a}	102.7^{b}	189.1	176.5^{b}	116.0^{c}	161.7^{ab}
57.5	214.5^{ab}	119.7^{a}	189.7	187.1^{a}	124.5^{b}	167.1^{a}
SE	5.01	3.43	4.32	4.36	3.02	3.34
CV (%)	2.9	3.8	2.8	3.2	3.1	2.6
P-value	0.05	0.002	0.379	<.001	<.001	0.027
IRS(cm)						
40	218.8^{a}	117.1^{a}	193.2^{a}	169.3^{b}	140.1^{a}	167.7^{a}
60	210.1^{b}	104.2^{b}	192.2^{a}	188.5^{a}	123.3^{b}	163.7^{ab}
80	209.4^{b}	119.5^{a}	183.7^{b}	164.8^{b}	109.8^{c}	157.4^{bc}
100	219.2^{a}	102.3^{b}	177.6^{b}	148.7^{c}	110.7^{c}	151.0^{c}
SE	4.65	5.79	5.68	6.31	6.41	4.06
CV (%)	0.6	0.8	1.8	0.6	1.4	0.3
P-value	0.002	<.001	<.001	<.001	<.001	0.001

Means with the same letter in a column are not significantly different; LF: Level of fertilizer; IRS: Inter-row spacing; CV: Coefficients of variation; SE: Standard errors of the mean

Table 4. Means ± SE of number of tillers per plant at harvest (number) of *Echinochloa* spp. at five locations

LF ($kgNha^{-1}$)	Location					Over all mean
	Banat	Humera	Kebabo	Ruwasa	Zerbabit	
0	13.48^{ab}	9.658	10.53	10.48^{c}	14.86^{ab}	11.75
11.5	12.42^{b}	9.658	10.22	8.90^{c}	13.08^{bc}	10.86
23.0	14.92^{a}	8.583	10.11	10.17^{bc}	12.24^{c}	11.19
34.5	12.74^{b}	9.000	9.62	9.67^{c}	16.68^{a}	13.60
46.0	12.14^{b}	8.667	10.43	12.78^{a}	13.18^{bc}	11.44
57.5	12.23^{b}	9.975	9.29	11.26^{b}	15.29^{ab}	11.61
SE	0.818	0.557	1.026	0.653	1.021	1.640
CV (%)	7.7	7.4	12.5	7.7	8.8	17.1
P-value	0.048	0.135	0.809	0.009	0.012	0.640
IRS(cm)						
40	9.57^{c}	8.328^{b}	9.79^{ab}	9.87	13.00^{bc}	11.46
60	12.54^{b}	8.322^{b}	9.19^{b}	10.21	11.87^{c}	10.43
80	15.27^{a}	10.194^{a}	10.27^{ab}	11.14	14.39^{b}	12.23
100	14.58^{a}	10.183^{a}	10.89^{a}	10.94	17.63^{a}	12.84
SE	0.982	0.712	0.836	1.099	1.200	1.245
CV (%)	2.1	4.2	6.5	1.7	4.0	4.0
P-value	<.001	0.002	0.035	0.355	<.001	0.253

Means with the same letters in a column are not significantly different; LF: Level of fertilizer; IRS: Inter-row spacing; CV: Coefficients of variation; SE: Standard errors of the mean

found that greater plant height at less dense row spacing.

3.6 Effect of Nitrogen Fertilizer on Number of Tillers per Plant at Harvest

There was no significant difference (p>0.05) on number of tillers per plant due to nitrogen fertilizer (Table 4). This indicates that nitrogen fertilizer had no significant effect on number of tillers per plant in the current study.

3.7 Effect of Spacing on Number of Tillers per Plant at Harvest

Spacing had no significant (p>0.05) effect on number of tillers at harvest (Table 4) and was contradict with the previous studies [17,18,19].

4. CONCLUSION AND RECOMMENDATIONS

This study indicated that nitrogen fertilizer and spacing influenced DMY, 50% flowering and plant height at harvest. Relatively higher DMY and plant height at harvest were obtained from 23.0, 34.5, 46.0 and 57.5 $kgNha^{-1}$ as compared with the other treatments set up. Moreover, higher and lower values of DMY and plant height at harvest were obtained from 40 and 80 cm spacing, respectively. The study suggested that application of 23.0 $kgNha^{-1}$ and 40 cm spacing improved biomass yield and plant height at harvest of Mezrut grass (*Echinochloa* spp.) under rain fed condition and recommended to be implemented. Therefore, application of 23.0 $kgNha^{-1}$ and 40 cm spacing to boost biomass yield of *Echinochloa* spp. should be demonstrated and popularized in the study area and other similar Ethiopian agro ecologies. In addition, further investigation should be conducted on the effect of N fertilizer on chemical composition of feed harvested at different maturity stage of *Echinochloa* spp.

DISCLAIMER

Authors declare and affirm that this is our own work. The authors have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of the activity. Any scholarly matter that is included in the activity has been given recognition through citation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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