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EFFECTS OF NITROGEN FERTILIZATION AND HARVEST TIME ON ROOT YIELD AND QUALITY OF FODDER BEET (*Beta vulgaris var. crassa* Mansf.)

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ABSTRACT

The effects of five nitrogen rates (0, 50, 100, 150 and 200 kg ha^{-1}) and four harvest times (1 September, 15 September, 1 October and 15 October) on root yield and yield components of fodder beet (*Beta vulgaris var. crassa* Mansf.) were evaluated under Isparta conditions in the 2007 and 2008 growing seasons. Nitrogen rates and harvest time significantly affected most of the yield components determined in fodder beet. Nitrogen applications increased root yield, dry matter yield, crude protein content, crude protein yield, root diameter and root length but decreased ADF and NDF contents of roots. Crude protein content decreased with advancing times while root yield, root dry matter yield, crude protein yield, root diameter, root length ADF and NDF contents of roots increased. Based on these results, 150 kg per hectare nitrogen treatments and third harvest time can be recommended for similar ecelogical conditions because of high crude protein yield in fodder beet.

Key words: fodder beet, root yield, yield components, neutral detergent fiber, acid detergent fiber

INTRODUCTION

One of the most important factors affecting the Turkish farming system is the lack of cheap, abundant, high quality feedstuff. The feeding of low-quality forages, such as crop residues (wheat, barley, straw) and low quality hays, are a common practice in Turkey (Bingöl et al. 2007). Fodder beet is successfully grown as a fodder crop in many European countries. The plant is used as a valuable source of fodder for cattle (Niazi et al. 2000). Since fodder beet contains high water and sugar, it increases milk product and is suitable forage for dairy cows. The fodder beet is used by mixing with straw in European countries. It is also reported that the plant is suitable to make silage (Akyıldız 1983, Özen et al. 1993).

Fodder beet has extremely high yield potential when grown on high fertile soils. Fodder beet requires large amounts of nitrogen. Nitrogen fertilizers are one of the major costs for production of these crops (Abdel-Gwad et al. 2008; Sahran and Ismail, 2003). Zamfir et al. (2001) and Zaki (1999) reported that increasing nitrogen fertilization increased dry matter yield and crude protein content of fodder beet.

Previous studies with fodder beet indicated that the nitrogen rates influenced root yield and yield components (Yüksel et al. 2009; Prokopenko et al. 1997; Geweifel and Aly, 1996; Karczmarczyk et al. 1995). However, field experiments on the effects of nitrogen rates and harvest time on the root yield and quality components are very limited in fodder beet.

The objective of the present study was to investigate the effects of different harvest time and nitrogen application rates on root yield and yield components of fodder beet. Our results were expected to be useful for assessing the optimal nitrogen rate and harvest time for the best root yield and quality of fodder beet, especially in the Mediterranean region of Turkey.

MATERIALS AND METHODS

The research was performed at Isparta (37º 45' N, 30º 33' E, elevation 1035 m) located on the Mediterranean region of Turkey during 2007 and 2008 growing season. The major soil characteristics, based on the method described by Rowell (1996) were found to be as follows; the soil texture was clay; organic matter was 1.2% by Walkley-Black method; total salt was 0.3%; lime was 7% by Schiebler calcimeter, extractable P by 0.5N $NaHCO_3$ extraction was 3.1 mg kg^{-1}; exchangeable K by 1N NH_4OAc was 125 mg kg^{-1}; pH was 8.1 in soil saturation extract. Soil type was calcareous fulvisol (Akgül and Başayiğit, 2005). Climatic data for the research area are given in Table 1. Fodder beet (*Beta vulgaris var. crassa* Mansf.) cultivar Ecdorot was obtained from Ankara University, Faculty of Agriculture.

Factorial arrangements of five nitrogen levels (0, 50, 100, 150 and 200 kg ha^{-1}) and four harvest time (1 September, 15 September, 1 October and 15 October) were evaluated in a randomized complete block design with three replications. Seeding rates were 30 kg ha^{-1}. Individual plot size was 3 x 5 m= 15 m^2. Sowing was done by hand on 24 and 27 March in 2007 and 2008, respectively. Half of the nitrogen fertilizer (Calcium ammonium nitrate 33%) and 10 kg ha^{-1} triple super phosphate (44%) were applied in sowing time, the rest of the nitrogen fertilizer were applied after first hoeing on all plots in both years. Plots were irrigated four times and three times through growing period in 2007 and 2008, respectively.

Table 1. Growing season total precipitation and mean temperature in the experimental area (March through October).

Months	Total rainfall (mm)			Mean temperature (°C)		
	1975-2008	2007	2008	1975-2008	2007	2008
March	61.9	33.8	51.4	5.8	7.1	8.4
April	51.0	14.8	49.2	10.7	9.5	11.5
May	59.7	13.4	24.6	15.4	17.5	14.4
June	36.0	16.6	4.8	19.7	21.6	20.9
July	11.9	1.5	1.6	23.1	25.1	23.6
August	10.4	10.6	19.4	22.8	24.3	24.6
September	19.2	1.6	21.2	18.4	18.3	18.9
October	40.4	25.0	56.5	13.1	14.4	13.1
Total	290.5	117.3	228.7	-	-	-
Mean	-	-	-	16.1	17.2	16.9

There were no problems with pests, diseases or weeds during the course of study.

10 plants from each replication were taken at harvest stage for morphological measurements. Root diameter and root length were measured in individual plants. Plots were harvested on 1 September, 15 September, 1 October and 15 October in 2007 and 2008, respectively.

Two square meters (2 times 1 m^2) area were harvested in each plot (Albayrak and Çamaş, 2006) in per harvest time. After harvest, fresh yields of roots were determined and samples were dried in ovens at 70 ^{o}C to a constant weight for dry matter content (Martin et al. 1990).

Dried samples were grounded and the amount of N was found by using kjehldal method (Kacar and İnal, 2008). Crude protein content was calculated multiplying N amount of each sample by 6.25. ADF (Acid detergent fiber) and NDF (Neutral detergent fiber) concentrations were determined according to standard laboratory procedures of forage quality analysis (Albayrak et al. 2009; Türk et al. 2009). Data were analyzed using the standard analysis of variance (ANOVA) technique and means were separated using the comparisons based upon the least significant difference (LSD) using GLM producers of SAS (1998).

RESULTS AND DISCUSSION

The results of ANOVA for root yield and yield components of fodder beet are summarized in Table 2. The results of variance analysis showed that the effects of nitrogen fertilization and harvest time were significant. Years were shown separately, because differences of years were significant for all parameters except root length and root diameter.

Root length and diameter: Increasing nitrogen treatments root length is also increased in both years (Table 3). Averages two years, the highest root length were determined in both 150 and 200 kg ha-1 nitrogen treatments (14.03 and 13.78 cm, respectively). An average of two years, root length increased by delayed harvest time. The longest root length (14.46 cm) was obtained from the last harvest time.

Table 2. Results of analysis of variance and mean squares of the traits determined. (HT): Harvest time, (F) Fertilization

Source of variance	df	Root yield	Root dry matter content	Root dry matter yield	Crude protein Content	Crude protein Yield	NDF	ADF	Root length	Root diameter
2007										
Block (b)	2	107 ^{ns}	0.05 ^{ns}	2.11 ^{ns}	0.12 ^{ns}	0.03 ^{ns}	2.09 ^{ns}	1.02 ^{ns}	1.67 ^{ns}	2.89 ^{ns}
HT	3	2294**	4.02**	58.3**	18.85**	0.11**	66.99**	37.3**	28.3**	34.99**
F	4	899**	0.03 ^{ns}	15.09**	3.94**	0.30**	25.00**	12.2**	16.6**	21.08**
HT x F	12	55 ^{ns}	0.01 ^{ns}	0.95 ^{ns}	0.49 ^{ns}	0.01 ^{ns}	0.12 ^{ns}	0.06 ^{ns}	1.57 ^{ns}	2.08 ^{ns}
Error	38	72.5	0.02	1.19	0.55	0.01	0.73	0.36	2.26	2.95
CV (%)		12.23	2.11	12.3	9.78	13.9	5.15	5.17	12.1	12.3
2008										
Block (b)	2	120 ^{ns}	0.05 ^{ns}	2.54 ^{ns}	0.17 ^{ns}	0.05 ^{ns}	1.28 ^{ns}	0.71 ^{ns}	6.14 ^{ns}	5.94 ^{ns}
HT	3	2929**	5.89**	81.9**	33.84**	0.21**	54.57**	25.9**	35.88**	44.27**
F	4	10008**	0.04 ^{ns}	17.9**	5.86**	0.52**	15.13**	8.47**	21.01**	25.59**
HT x F	12	63.1 ^{ns}	0.01 ^{ns}	1.16 ^{ns}	0.72 ^{ns}	0.02 ^{ns}	0.09 ^{ns}	0.04 ^{ns}	2.52 ^{ns}	2.85 ^{ns}
Error	38	81.09	0.02	1.42	0.82	0.02	0.44	0.25	3.25	3.61
CV (%)		9.81	1.07	10.1	7.77	10.9	4.14	4.12	13.9	13.2
Average of two years										
Year (Y)	1	735**	3.87**	27.3**	129**	3.02**	624**	169**	7.48 ^{ns}	3.69 ^{ns}
Block(year)	4	113 ^{ns}	0.05*	2.32 ^{ns}	0.15 ^{ns}	0.04 ^{ns}	1.69*	0.87*	3.89 ^{ns}	4.41 ^{ns}
HT	3	5204**	9.79**	139**	51.6**	0.31**	120.9**	62.8***	63.5**	78.9**
Y x HT	3	20 ^{ns}	0.12**	1.05 ^{ns}	1.12 ^{ns}	0.009 ^{ns}	0.58 ^{ns}	0.51 ^{ns}	0.60 ^{ns}	0.37 ^{ns}
F	4	1906***	0.07**	32.9**	9.71**	0.80**	39.5**	20.47**	37.3**	46.3**
Y x F	4	1.55 ^{ns}	0.0001 ^{ns}	0.06 ^{ns}	0.09 ^{ns}	0.01 ^{ns}	0.62 ^{ns}	0.17 ^{ns}	0.25 ^{ns}	0.34 ^{ns}
HT x F	12	118 ^{ns}	0.02 ^{ns}	2.11 ^{ns}	1.20 ^{ns}	0.02 ^{ns}	0.20 ^{ns}	0.10 ^{ns}	3.73 ^{ns}	4.62 ^{ns}
Y x HT x F	12	0.14 ^{ns}	0.0001 ^{ns}	0.006 ^{ns}	0.01 ^{ns}	0.0006 ^{ns}	0.01 ^{ns}	0.0007 ^{ns}	0.36 ^{ns}	0.30 ^{ns}
Error	76	76.81	0.02	1.31	0.69	0.02	0.59	0.30	2.75	3.28
CV (%)		11.3	1.63	11.4	8.81	12.6	4.62	4.78	13.1	12.8

df, degrees of freedom; CV, coefficient of variation; ns, not significant. *$P < 0.05$, **$P < 0.01$.

Table 3. Root yield and its components of fodder beet in different nitrogen fertilization and harvest time

Treatments	Root yield (t ha^{-1})	Root dry matter content (%)	Root dry matter yield (t ha^{-1})	Crude protein Content (%)	Crude protein Yield (t ha^{-1})	NDF (%)	ADF (%)	Root length (cm)	Root diameter (cm)
2007									
Nitrogen Fertilization (kg ha^{-1})									
0	75.85 c	12.33	9.39 c	8.62 b	0.80 d	22.35 a	15.60 a	10.98 c	12.33 d
50	80.62 c	12.37	10.01 c	9.45 a	0.93 c	21.19 b	14.79 b	11.53 bc	12.95 cd
100	87.75 b	12.41	10.94 b	9.74 a	1.05 b	20.82bc	14.53bc	12.53ab	14.07bc
150	93.17ab	12.48	11.68 ab	9.91 a	1.14 ab	20.20 c	14.10 c	13.60 a	15.49 a
200	96.81 a	12.40	12.07 a	10.07 a	1.18 a	18.43 d	12.86 d	13.55 a	14.97 ab
Harvest time									
1-September	71.37 d	11.75 d	8.39 d	10.73 a	0.90 b	18.06 d	12.42 d	11.01 c	12.26 c
15-September	83.20 c	12.27 c	10.21 c	10.08 b	1.03 a	19.86 c	13.91 c	11.81 bc	13.28 bc
1-October	92.98 b	12.59 b	11.71 b	9.29 c	1.09 a	21.54 b	15.09 b	12.73 b	14.54 ab
15-October	99.82 a	12.98 a	12.96 a	8.13 d	1.06 a	22.94 a	16.08 a	14.20 a	15.77 a
2008									
Nitrogen Fertilization (kg ha^{-1})									
0	80.15 c	12.69	10.21 c	10.49 c	1.04 d	17.40 a	13.02 a	11.35 d	12.56 c
50	85.21 c	12.73	10.90 c	11.50 b	1.22 c	16.50 b	12.34 b	11.92 cd	13.19 bc
100	92.75 b	12.77	11.90 b	11.86 ab	1.38 b	16.21 bc	12.13 bc	12.95 bc	14.32 ab
150	98.49ab	12.84	12.71 ab	12.06 ab	1.50 ab	15.73 c	11.77 c	14.46 a	15.77 a
200	102.35a	12.77	13.14 a	12.26 a	1.55 a	14.35 d	10.74 d	14.01 ab	15.74 a
Harvest time									
1-September	74.10 d	12.03 d	8.92 d	13.15 a	1.17 b	13.59 d	10.37 d	11.19 b	12.48 c
15-September	88.13 c	12.57 c	11.08 c	12.35 b	1.36 a	15.60 c	11.62 c	12.24 b	13.52 bc
1-October	98.49 b	12.90 b	12.70 b	11.38 c	1.44 a	16.92 b	12.60 b	13.60 a	14.80 b
15-October	106.44a	13.53 a	14.39 a	9.66 d	1.38 a	18.03 a	13.42 a	14.72 a	16.46 a
Average of two years									
Nitrogen Fertilization (kg ha^{-1})									
0	78.00 c	12.51 b	9.80 d	9.55 c	0.92 d	19.88 a	14.31 a	11.17 c	12.44 c
50	82.92 c	12.55 b	10.46 c	10.48 b	1.08 c	18.84 b	13.57 b	11.73 c	13.07 c
100	90.25 b	12.59 ab	11.42 b	10.80 ab	1.21 b	18.52 b	13.33 b	12.74 b	14.20 b
150	95.83 a	12.66 a	12.20 a	10.99 a	1.32 a	17.97 c	12.94 c	14.03 a	15.63 a
200	99.58 a	12.58 ab	12.61 a	11.17 a	1.37 a	16.39 d	11.80 d	13.78 a	15.36 a
Harvest time									
1-September	72.73 d	11.89 d	8.65 d	11.94 a	1.03 c	15.82 d	11.39 d	11.10 d	12.37 d
15-September	85.67 c	12.42 c	10.64 c	11.22 b	1.20 b	17.73 c	12.77 c	12.03 c	13.40 c
1-October	95.73 b	12.74 b	12.21 b	10.34 c	1.27 a	19.23 b	13.85 b	13.17 b	14.67 b
15-October	103.13a	13.25 a	13.68 a	8.89 d	1.22 ab	20.49 a	14.75 a	14.46 a	16.12 a

Means followed by the same columns are not significantly different at p=0.05 level

Increasing nitrogen treatments root diameter is also increased in both years, just like the root length (Table 3). Averages two years, the highest root diameter were determined in both 150 and 200 kg ha^{-1} nitrogen treatments (15.63 and 15.36 cm, respectively). An average of two years, root diameter increased by delayed harvest time. The highest root diameter (16.12 cm) was determined in the last harvest time (15 October).

It was previously reported that root length and diameter in fodder beet ranged from 7.50 to 12.99 cm and 13.51 to 24.70 cm, respectively (Albayrak and Çamaş, 2005; Albayrak and Çamaş, 2006; Parlak and Ekiz, 2008). Present results similar to those researchers' findings.

Root dry matter content: Both first and second year, nitrogen fertilization no effect dry matter content of fodder beet. However, dry matter content of fodder beet roots slightly increased by delayed harvest time. The highest dry matter content was determined in last harvest time (13.25%). Although there were no statistically significant differences among the rates of root dry matter, it was relatively lower in control plots than 200 kg ha^{-1} nitrogen fertilization. An average of two years, root dry matter content increased by delayed harvest time. The highest root dry matter content (12.66%) was obtained from the last harvest time (15 October). Similarly, increasing nitrogen treatments resulted in slightly increased dry matter contents of fodder beet roots. It was previously reported that rates of dry matter in fodder beet might change from 11.82 % to 18.60 % (Rzekonowski 1994, Lukic and Vasilijevic 1996, Avcıoğlu et al. 1999, Soya et al. 1999). Prokopenko et al. (1997) found that dry matter content of the fodder beet increased directly with the level of fertilization. This result is consistent with the present results.

Root crude protein, ADF and NDF contents: In the first year, comparing means of average crude protein contents of nitrogen fertilization applications, the plots having 50, 100, 150 and 200 kg ha^{-1} doses applications were statistically in the same group, but there was statistically difference between these nitrogen fertilizer applications and control. In the second year, the plots having 100, 150 and 200 kg ha^{-1} doses applications were statistically in the same group. Average of two years, the highest crude protein contents were obtained from 100, 150 and 200 kg ha^{-1} nitrogen treatments (10.80, 10.99 and 1.17%, respectively). In both first and second year, crude protein content decreased by delayed harvest time. The highest crude protein content was determined in first harvest time in both years (10.73 and 13.75%, respectively).

Both first and second year, increasing nitrogen treatments resulted in a reduced both NDF and ADF contents of fodder beet roots. However, NDF and ADF contents of roots increased by delayed harvest time. An average of two years, the highest NDF content of root was obtained from control plots (19.88%) and last harvest time (20.49%). Similarly, the highest ADF content of root was obtained from control plots (14.31%) and last harvest time (14.75%).

Abdel-Gwad et al. (2008) reported chemical compositions (crude protein, ash, total digestible nutrients and digestible crude protein) of fodder beet were significantly increased by increasing nitrogen fertilizer level, while crude fibers take an opposite trend. Zamfir et al. (2001) indicated that the fertilizer application determined the increase of both organic matter and macronutrients content. Avarvarei (1999) demonstrated that the fodder beet was given 100, 150 or 200 kg ha^{-1} nitrogen fertilizer. Researcher also reported that fertilizer application increased organic matter digestibility, except for that of cellulose. Abdel-Gwad et al. (1997) found that fresh and dry matter yield and crude protein and total carbohydrate concentration of roots generally increased with increasing fertilizer rate for all fertilizers, while fibre concentration decreased. Geweifel and Aly (1996) reported that root dry matter yield and CP content of foder beet increased directly with the level of fertilization. Fertilizer was decreased crude fiber content of roots. These results are consistent with the present results.

Root yield: In the first year, the highest root yield (96.81 t ha^{-1}) was obtained from 200 kg ha^{-1} nitrogen application. 150, 100 and 50 kg ha^{-1} nitrogen application and control plots (93.17, 87.75, 80.62 and 75.85 t ha^{-1}, respectively) followed the highest yield (Table 3). Comparing means of average root yields of nitrogen fertilizer applications, the plots having 150 and 200 kg ha^{-1} doses applications were statistically in the same group. In the first year of study, the highest root yield (99.82 t ha^{-1}) was obtained from last harvest time (15 October). As comparison to harvest time (first harvest time, 1 September) the increase of root yield was 39.9% in last harvest time (15 October). Root yields of second year of the study are higher than that of the first year. Comparing means of average root yields of nitrogen fertilizer applications, the highest root yield (102.35 t ha^{-1}) was obtained from 200 kg ha^{-1} nitrogen dose application. The second highest root yield (98.49 t ha^{-1}) was obtained from 150 kg ha^{-1} nitrogen dose application and there was no statistically difference both nitrogen applications. As comparison to harvest time (first harvest time, 1 September) the increase of root yield was 43.6% in last harvest time (15 October) in the second year.

In terms of average nitrogen fertilizer application in different doses, the highest root yield (99.58 t ha^{-1}) was determined in 200 kg ha^{-1} nitrogen fertilizer dose application. But there were no statistically differences between root yield of 200 kg ha^{-1} nitrogen fertilizer dose application and that of 150 nitrogen fertilizer application (95.83 t ha^{-1}). The lowest root yield (78.00 t ha^{-1}) was obtained form the control plots. An average of two years, root yield increased by delayed harvest time. The highest root yield (103.13 t ha^{-1}) was obtained from the last harvest time (15 October). It was found that the yield of fodder beet roots significantly increased increasing nitrogen doses (Gasiorowska and Ceglarek, 1996; Ceglarek and Gasiorowska, 1997). Moller and Soegaard (1998) reported that fodder beet roots were harvested on 29 September, 13 October, 27 October or 10 November. Root yields increased from the end of September to the end of October. The increase in yield of fodder beet roots with a delayed harvest time. These results are consistent with the present results.

Root dry matter yield: The highest root dry matter yield was obtained from 200 kg ha-1 nitrogen treatment in both years (12.07 and 13.14 t ha^{-1}, respectively). But there were no statistically differences between root dry matter yield of 200 kg ha^{-1} nitrogen fertilizer dose application and that of 150 nitrogen fertilizer application in both years (11.68 and 12.71 t ha^{-1}). An average two years, the highest root dry matter yields were determined in both 200 and 150 kg ha-1 nitrogen treatments (12.61 and 12.20 t ha^{-1}). An average of two years, root dry matter yield increased by delayed harvest time. The highest root dry matter yield (13.68 t ha^{-1}) was obtained from the last harvest time (15 October). Bieniaszewski et al. (1995) reported that root dry matter yields increased from 8.36 to 9.68 t ha^{-1} with increasing nitrogen rates. Lukic and Vasiljevic (1996) found that root yield of fooder beet was 11.3 t ha^{-1}. Grzes et al. (1996) found that average dry matter yields were highest with 160 kg ha^{-1} nitrogen fertilization. Sarhan and Ismail (2003) reported that root dry matter yield and crude protein yield of fodder beet was significantly increased by increasing nitrogen fertilizer level. These results are consistent with the present results.

Root crude protein yield: The control plots produced significantly less root crude protein yield in all fertilizer levels. The 2-year average root crude protein yields from the 0, 50, 100, 150 and 200 kg N ha^{-1} treatments were 0.92, 1.08, 1.21, 1.32 and 1.37 tons per hectare, respectively (Table 3). The highest root crude protein yield was obtained from 200 kg ha-1 nitrogen treatment in both years (1.18 and 1.55 t ha^{-1}, respectively). There were no statistical significant differences between root crude protein yield of 200 kg ha^{-1} nitrogen fertilizer dose application and that of 150 nitrogen fertilizer application in both years (1.14 and 1.32 t ha^{-1}). An average two years, the highest root crude protein yields were determined in both 200 and 150 kg ha-1 nitrogen treatments (1.32 and 1.37 t ha^{-1}).

In both years, comparing means of average root crude protein yields of harvest time, 2, 3 and 4th harvest times were statistically in the same group, but there was statistical significant difference between these harvest times and first harvest time. In both first and second year, crude protein yield increased by delayed harvest time. The highest crude protein yield was determined in 3 and 4th harvest time in both years (1.27 and 1.22 t ha^{-1}, respectively).

Karczmarczyk et al. (1995) reported that root crude protein content and crude protein yield of fodder beet increased with increasing nitrogen rate. Similarly, Prokopenko et al. (1997) indicated that crude protein yield of the fodder beet increased directly with the level of fertilization. Zaki (1999) found that root dry matter yield and crude protein yield of fodder beet was significantly increased by increasing nitrogen fertilizer level. These results are consistent with the present results.

CONCLUSION

The results from the different nitrogen rates and harvest times applied in fodder beet in Mediterranean conditions of Turkey can be summarized as follows:

(1) Increasing N rates resulted in increased root yield of fodder beet.

(2) The highest root dry matter and crude protein yields were obtained from the 200 kg ha^{-1} nitrogen rate.

(3) There were no statistical significant difference between 150 and 200 kg ha^{-1} nitrogen fertilizer applications in terms of dry matter and crude protein yields.

(4) As nitrogen rate increased from 0 to 200 kg ha^{-1}, ADF and NDF contents of fodder beet roots showed a decrease.

(5) Root yield and quality changed with harvest times.

(6) Delaying harvest time resulted in increase root yield but decreased root quality of fodder beet.

(7) Based on these results, 150 kg per hectare nitrogen treatments and third harvest time can be recommended for similar ecological conditions because of high crude protein yield in fodder beet.

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