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# Promising spring durum wheat lines resistant to brown rust in northern Kazakhstan

Yelzhas Kairzhanov, Sandukash Babkenova, Adylkhan Babkenov, Ruslan Zhylykybaev, Maral Utebayev, Tatyana Zhigula, Aidos Sayanov

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1 **PROMISING SPRING DURUM WHEAT LINES RESISTANT TO BROWN RUST IN**  
2 **NORTHERN KAZAKHSTAN**

3 Sandukash Amantaevna BABKENOVA, <https://orcid.org/0000-0002-3239-5575>

4 Adylkhan Temirkhanovich BABKENOV, <https://orcid.org/0000-0001-9939-0966>

5 Ruslan Sagynayevich ZHYLKYBAEV, <https://orcid.org/0009-0007-2972-8993>

6 Maral Uralovich UTEBAYEV, <https://orcid.org/0000-0003-0729-0592>

7 Tatyana Yurievna ZHIGULA, <https://orcid.org/0000-0001-9033-6111>

8 Aidos Tugelbergenuly SAYANOV, <https://orcid.org/0000-0001-6594-2160>

9 Yelzhas Konspekovich KAIRZHANOV \*, <https://orcid.org/0000-0002-2630-6919>

10 A.I. Barayev Research and Production Centre for Grain Farming, Akmola region, Kazakhstan

11 \*Email: [yelzhas\\_90@mail.ru](mailto:yelzhas_90@mail.ru)

12 **Key words:** spring durum wheat, variety, brown rust, resistance, grain quality

13 **Palavras-chave:** trigo de primavera, variedade, ferrugem marrom, resistência, qualidade do grão

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**27 Abstract**

28           The breeding of spring durum wheat varieties resistant to leaf rust is considered a topical  
29 issue. The aim of our research is to identify promising spring durum wheat lines resistant to leaf  
30 rust with a complex of economically valuable traits. In 2022-2024, 163 spring durum wheat lines  
31 were studied for resistance to brown rust, growing season, grain yield, specific weight,  
32 vitreousness, and protein content. Immunological evaluation of spring durum wheat varieties was  
33 carried out using standard laboratory methods on seedlings grown in a greenhouse. The physical  
34 and physicochemical properties of the grain were evaluated using standard methods. The selected  
35 spring durum wheat samples will be recommended to breeders as sources of resistance to leaf rust,  
36 as well as sources of high quality for the creation of new competitive varieties adapted to the  
37 conditions of Northern Kazakhstan.

38

**39 Resumo**

40           O melhoramento de variedades de trigo duro de primavera resistentes à ferrugem da folha  
41 é considerado um tema de grande relevância. O objetivo desta pesquisa é identificar linhagens  
42 promissoras de trigo duro de primavera resistentes à ferrugem da folha e que apresentem um  
43 conjunto de características economicamente valiosas. Entre 2022 e 2024, 163 linhagens de trigo  
44 duro de primavera foram estudadas quanto à resistência à ferrugem marrom, ciclo de crescimento,  
45 produtividade de grãos, peso específico, vitrificação e teor de proteína. A avaliação imunológica  
46 das variedades de trigo duro de primavera foi realizada utilizando métodos laboratoriais padrão  
47 em plântulas cultivadas em casa de vegetação. As propriedades físicas e físico-químicas dos grãos  
48 foram avaliadas por meio de métodos padrão. As amostras selecionadas de trigo duro de primavera  
49 serão recomendadas aos melhoristas como fontes de resistência à ferrugem da folha, bem como  
50 fontes de alta qualidade para a criação de novas variedades competitivas adaptadas às condições  
51 do norte do Cazaquistão.

52

## 53 **1.Introduction**

54 Kazakhstan is one of the major producers of spring wheat and ranks among the top ten  
55 grain exporters to the global market (TASS, 2024). In 2024, Kazakhstan harvested a record grain  
56 crop of 26.6 million tons, with an average yield of 16 centners per hectare (KazTAG, 2024).

57 The majority of grain supplied to the global market is produced in Northern Kazakhstan.  
58 The main factors constraining yield growth in this region include the sharply continental climate,  
59 limited precipitation during the growing season, and the widespread occurrence of diseases in  
60 wheat crops.

61 One of the most significant factors reducing both yield and grain quality in durum wheat  
62 (*Triticum durum*) is infection by fungal diseases, including leaf rust caused by *Puccinia triticina*  
63 Erikss.

64 Infection with leaf rust causes significant yield losses in wheat, exceeding 40% even at  
65 early stages, and affects extensive geographic areas (Koyshybayev, 2018). The occurrence of leaf  
66 rust in Northern Kazakhstan is recorded annually, except in drought years. Epiphytotic of this  
67 disease were observed five times during the period from 2003 to 2024.

68 This disease disrupts the functioning of the photosynthetic apparatus, leading to leaf  
69 desiccation and a reduction in the thousand-kernel weight (Babkenov et al., 2023). The  
70 development of leaf rust also results in shriveled grain, reduced flour yield, and deterioration of  
71 key wheat quality parameters (Ellis et al., 2023).

72 The main methods for controlling this disease include agronomic, chemical, and biological  
73 approaches. However, from both economic and environmental perspectives, the most effective  
74 strategy is the cultivation of resistant varieties.

75 To date, more than 80 genes conferring resistance to leaf rust have been identified in wheat  
76 (Kumar et al., 2022); however, most of them are ineffective against pathogen populations in  
77 Kazakhstan. Traditionally, resistance genes are classified as seedling (juvenile) and adult plant

78 genes: the former generally confer resistance at all stages of plant development, whereas the latter  
79 provide resistance only at later growth stages (McIntosh et al., 1995).

80 At present, only a limited number of durum wheat varieties resistant to leaf rust are  
81 cultivated in Northern Kazakhstan. Therefore, breeding programs aimed at developing varieties  
82 resistant to leaf rust are essential for reducing yield losses, increasing total grain production, and  
83 enhancing the country's export potential, making this a highly relevant objective.

84 The aim of this study was to identify promising spring durum wheat lines resistant to leaf  
85 rust and possessing a set of economically valuable agronomic traits.

86

## 87 **2. Materials and Methods**

88 The climate of Northern Kazakhstan is sharply continental and characterized by  
89 pronounced temporal and spatial variability. Winters are cold, while summers are hot, with sharp  
90 fluctuations in air temperature and uneven distribution of precipitation, accompanied by strong  
91 wind activity.

92 The summer period is characterized by high temperatures and low relative humidity. On  
93 average, about 140 mm of precipitation falls during the summer months, with annual variations  
94 ranging from 60 to 265 mm. A distinctive feature of the regional climate is a prolonged dry period  
95 (late May–June), during which, in some years, precipitation is extremely limited.

96 In 2022, the meteorological conditions during the growing season of spring wheat were  
97 characterized as dry (hydrothermal coefficient,  $HTC = 0.6$ ). A total of 100.3 mm of precipitation  
98 was recorded in June, July, and August, which is 36.0 mm below the long-term average (Figure  
99 1). Thus, hot and dry weather prevailed throughout the growing season, which was not conducive  
100 to high yield formation or to the development of foliar and stem diseases.

101 In 2023, the meteorological conditions during the growing season of spring wheat were  
102 characterized as extremely dry (hydrothermal coefficient,  $HTC = 0.2$ ). A total of 36.5 mm of

103 precipitation was recorded in June, July, and August, which is 99.8 mm below the long-term  
104 average.

105 Thus, hot and extremely dry weather prevailed throughout the growing season, which was  
106 not conducive to the formation of high yields or to the development of foliar and stem diseases.

107 In 2024, the meteorological conditions during the growing season of spring wheat were  
108 characterized as wet (HTC = 1.3). A total of 232.2 mm of precipitation was recorded in June, July,  
109 and August, which is 95.9 mm above the long-term average of 136.3 mm.

110 Thus, hot and wet weather prevailed throughout the growing season, which favored high  
111 yield formation and the development of foliar and stem diseases.

112 The juvenile resistance of spring durum wheat lines to the local population of the leaf rust  
113 pathogen was studied under greenhouse conditions at the Plant Disease Immunity Laboratory,  
114 based at the “Scientific and Production Center of grain farming named after A.I. Barayev” LLP in  
115 Akmola Region. A total of 163 spring durum wheat lines were used as plant material. The durum  
116 wheat cultivar Damsinskaya 90, which is susceptible to leaf rust, served as the standard.

117 The following agronomically important traits were evaluated: growing period, grain yield,  
118 resistance to leaf rust, protein content, thousand-kernel weight, and vitreousness.

119 The phytopathological assessment was conducted on seedlings using a standard laboratory  
120 method under controlled temperature and humidity conditions (Jin et al., 2007). The inoculum  
121 consisted of a composite population of *Puccinia triticina* Erikss., collected during survey  
122 inspections of commercial spring wheat fields.

123 Leaves infected with leaf rust were collected from wheat fields, and the urediniospores of  
124 the fungus were multiplied on the susceptible cultivar Damsinskaya 90. Seeds of each wheat line  
125 were sown, 10–12 seeds per line, in 4000-ml plastic containers. After inoculation, the seedlings  
126 were incubated in a moist chamber in darkness at  $18 \pm 2$  °C and 100% relative humidity for 14  
127 hours.

128           The seedling reaction to inoculation with the leaf rust spore suspension was assessed on  
129 the 14th day using the standard 4-point Stakman scale (Stakman et al., 1962).

130           The type of reaction to leaf rust was evaluated using the scale of E. B. Mains and H. S.  
131 Jackson (Mains et al., 1926): 0 – immune, no disease symptoms; 0; – necrosis without pustules; 1  
132 – highly resistant, very small pustules surrounded by necrosis; 2 – moderately resistant, medium-  
133 sized pustules surrounded by necrosis or chlorosis; 3 – moderately susceptible, medium-sized  
134 pustules without necrosis; 4 – highly susceptible, large pustules without necrosis; X –  
135 heterogeneous type, pustules of different types on the same leaf, with the presence of chlorosis  
136 and necrosis.

137           Seedlings with leaf segments showing reaction types 0, 0; and 1 were classified as resistant  
138 (R); types 1–2 and 2 as moderately resistant (MR); types 2–3 and X as moderately susceptible  
139 (MS); and types 3 and 4 as susceptible (S).

140           The physical and physicochemical properties of the grain were determined, including test  
141 weight, vitreousness, and protein content (ISO 7971-1:2009; GOST 10987-76; Sadkiewicz, 2005).

142           Statistical analysis was performed using several statistical software packages. The primary  
143 tools included SNEDECOR (designed for agricultural trials), Microsoft Excel for preliminary  
144 calculations and data structuring, STATISTICA 10 for advanced descriptive statistics and  
145 ANOVA, as well as R (version 4.x) for multivariate analysis, including correlation matrices and  
146 hierarchical clustering.

147

### 148 **3. Results**

149           Between 2022 and 2024, an immunological assessment was conducted on 163 lines from  
150 the spring durum wheat breeding laboratory at the “SPC GF named after A.I. Barayev” LLP.  
151 According to our results, 12 lines were characterized by absolute resistance to leaf rust, including  
152 272-08-9, 156-11-9, 156-11-10, 250-06-14, 88-12-6, and others. One line, 221-15-4, was classified  
153 as highly resistant. Three lines 214-12-14, 299-14-6, and 177-05 were considered moderately

154 resistant. Ten lines, including 333-05-5, 203-00-2, 148-11-1, 88-10-14, and 272-08-14, showed  
155 moderate susceptibility (Table 1).

156 The vegetation period of the studied lines varied between 91 and 99 days, and on average  
157 for the studied samples it was 94.9 days, while for the standard variety Damsinskaya 90 it was 94  
158 days. Six lines 272-08-9, 202-15-4, 206-08-1, 299-14-6, 221-15-4, and 156-11-9 matured 1–3 days  
159 earlier than the standard (Table 2 and 3).

160 Over the three-year study period, the average grain yield of the standard variety  
161 Damsinskaya 90 was 22.8 c/ha, while the studied lines ranged from 16.1 to 28.8 c/ha and on  
162 average, this figure was 23.3 c/ha. Nine lines 272-08-9, 156-11-9, 156-11-10, 88-12-6, 339-13-8,  
163 88-10-14, 299-14-6, 250-06-14, and 221-15-4 significantly exceeded the standard in yield.

164 Protein content in the promising lines varied from 14.7% to 17.8%, compared to 16.3% in  
165 the standard variety. Eight lines 88-12-6, 339-13-8, 299-14-6, 88-10-14, 356-11-24, 250-06-14,  
166 221-15-4, and 177-05 exhibited higher protein content than the standard.

167 The average natural weight of the Damsinskaya 90 standard over three years of study was  
168 746 g/l, while that of the lines studied varied from 690 to 780 g/l. Eleven samples exceeded the  
169 standard variety in this respect: 339-13-8, 82-12-11, 299-14-6, and others.

170 The vitreousness of the studied samples varied from 54 to 61%, while for the Damsinskaya  
171 90 standard it was 59%. Two lines exceeded the standard for this characteristic: 339-13-8 and 339-  
172 13-8.

173 A correlation analysis of the average values of the main agronomic traits of spring wheat  
174 for 2022–2024 revealed that most relationships between traits associated with leaf rust resistance  
175 were not statistically significant ( $p < 0.05$ ) (Figure 2). Moderate positive correlations were  
176 observed between the growing season and protein content ( $r = 0.38$ ), between the growing season  
177 and vitreousness ( $r = 0.38$ ), and between yield and test weight ( $r = 0.48$ ). Thus, with an increase  
178 in the growing season, protein content and vitreousness increase, and with an increase in yield, the  
179 test weight of the average values of the studied samples increases.

#### 180 4. Discussion

181 In Northern Kazakhstan, spring wheat varieties susceptible to brown rust are mainly  
182 cultivated, therefore, it is very important to develop varieties resistant to this disease. Among the  
183 163 spring durum wheat lines studied, 16 samples were identified as resistant to brown rust,  
184 accounting for 9.8%. This low percentage is consistent with the results of other researchers  
185 (Babkenov et al., 2019; Tajibayev et al., 2023).

186 Wheat grain yield is an integral indicator that receives significant attention in breeding  
187 programs. This indicator depends on many factors, such as soil, weather conditions, diseases,  
188 pests, etc. In our studies, the yield of the spring durum wheat lines studied ranged from 16.1 to  
189 28.8 cwt/ha, which is consistent with data obtained in studies by other scientists carried out in  
190 Northern Kazakhstan (Morgounov et al., 2022; Shamanin et al., 2021; Dolinny et al., 2025).

191 Protein content is one of the main criteria determining the quality of wheat grain. It  
192 determines not only the nutritional value of the grain and its processed products, but also the  
193 technological properties of flour. According to this indicator, the standard variety Damsinskaya  
194 90 was characterized by a high protein content (16.3%), which can be explained by favorable  
195 weather conditions during the grain filling period. This indicator meets the requirements for strong  
196 wheat, which is consistent with the data of other researchers (Dashkevich et al., 2022). When  
197 selecting grain quality in breeding programs, it is recommended to pay close attention to indicators  
198 such as protein content, as it is often at a restrictive minimum that does not allow for high-quality  
199 grain to be obtained in years with varying weather conditions (Helguera et al., 2020). According  
200 to the results of studies conducted in 2022-24, three lines should be highlighted: 88-12-6, 339-13-  
201 8, and 299-14-6, which are characterized by a complex of economically valuable traits. Line 339-  
202 13-8 is completely resistant to leaf rust, exceeds the standard variety Damsinsky 90 in yield by 3.9  
203 c/ha, in protein content by 0.3%, in specific weight by 24 g/l, vitreousness by 2%, and matures at  
204 the same rate as the standard variety. Line 88-12-6 is characterized by absolute resistance to brown  
205 rust and exceeds the standard in terms of yield by 0.5 c/ha and protein content by 0.5%.

206 Line 299-14-6 showed moderate resistance to leaf rust and yielded 25.4 c/ha, which is 2.6  
207 c/ha higher than Damsinskaya 90. Its protein content exceeded the standard by 0.6%, by 34 g/l in  
208 terms of specific weight, and ripened one day earlier than the standard variety.

209

## 210 **5. Conclusions**

211 Thus, over three years of research, 16 samples resistant to brown rust were selected from  
212 163 spring durum wheat lines studied: 272-08-9, 156-11-9, 156-11-10, 250-06-14, 88-12-6, and  
213 others. Nine lines significantly exceeded the yield of the standard variety Damsinskaya 90: 272-  
214 08-9, 156-11-9, 156-11-10, 88-12-6, 339-13-8, 88-10-14, 299-14-6, 250-06-14, and 221-15-4.  
215 Eight samples showed high protein content compared to the standard: 88-12-6, 339-13-8, 299-14-  
216 6, 88-10-14, 356-11-24, 250-06-14, 221-15-4, 177-05. Eleven lines exceeded the standard variety  
217 in terms of actual weight: 339-13-8, 82-12-11, 299-14-6, etc. Two lines were identified that  
218 exceeded the standard in terms of vitreousness: 339-13-8 and 339-13-8.

219 Three lines were selected based on a set of economically valuable traits: 88-12-6, 339-13-  
220 8, and 299-14-6. The selected spring durum wheat samples will be recommended to breeders as  
221 sources of resistance to leaf rust, as well as sources of high quality for the creation of new  
222 competitive varieties adapted to the conditions of Northern Kazakhstan. Currently, three lines: 88-  
223 12-6, 339-13-8, and 299-14-6 are being actively propagated and prepared for transfer to state  
224 variety testing.

## 225 **Authors' contributions**

226 S.A. Babkenova and A.T. Babkenov conceived and designed the study.

227 R.S. Zhylykbaev, M.U. Utebayev and T.Yu. Zhigula conducted the experiments and collected  
228 the data.

229 A.T. Sayanov participated in the data analysis.

230 Y.K. Kairzhanov supervised the research and contributed to manuscript preparation and editing.

231 All authors read and approved the final manuscript.

232 **Conflict of interest**

233 The authors declare that they have no conflict of interest regarding the publication of this paper.

234

235 **Data availability statement**

236 The data supporting the findings of this study are included in the manuscript.

237

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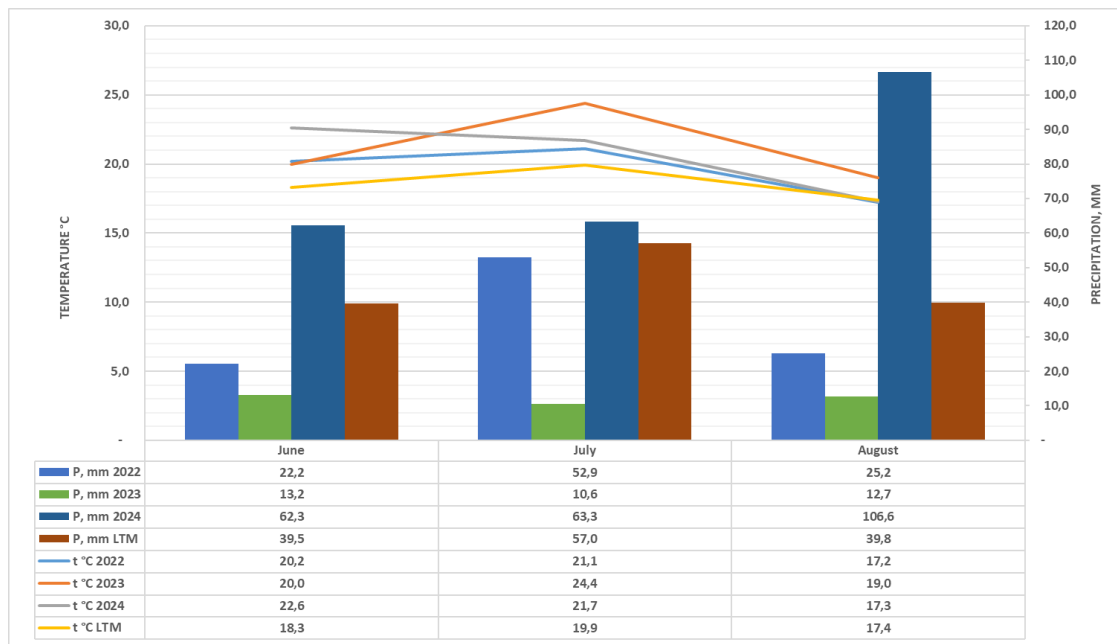
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309

310 **Figure 1.** Average Monthly Temperature and Precipitation During the Growing Season (June–  
 311 August) in 2022–2024

312

313 Table 1 – Immunological evaluation of spring durum wheat varieties for resistance to brown rust  
 314 (2022-2024, Akmola region)

Variety, line	Disease	
	Type of reaction, score	Intensity, %
Damsinskaya 90, st	4	80
272-08-9	0	0
156-11-9	0	0
156-11-10	0	0
250-06-14	0	0
88-12-6	0	0
339-13-8	0	0
202-15-4	0	0
73-15-11	0	0
33-15-16	0	0
206-08-1	0	0
356-11-24	0	0
82-12-11	0	0
221-15-4	1	10
177-05	2	5
214-12-14	2	5
299-14-6	2	5

315

316

317 Table 2 – Economically valuable characteristics of spring durum wheat lines (2022-2024, Akmola  
318 region)

Variety, line	Vegetation period, days	Yield, c/ha	Protein content, %	Net weight, g/l	Vitreousness, %
Damsinskaya 90, st.	94	22,8	16,3	746	59
272-08-9	91	24,2	15,4	753	54
156-11-9	93	28,2	15,7	763	55
156-11-10	97	26,5	16,3	753	58
88-12-6	96	23,3	16,8	746	54
339-13-8	95	26,7	16,6	770	61
202-15-4	92	16,1	16,1	690	57
73-15-11	94	19,9	15,9	702	57
33-15-16	99	20,6	16,0	699	59
214-12-14	95	22,7	15,8	723	58
299-14-6	93	25,4	16,9	780	59
206-08-1	92	21,3	14,7	761	54
88-10-14	99	28,0	16,8	757	56
356-11-24	98	17,7	17,4	761	58
82-12-11	96	18,8	16,2	771	57
250-06-14	97	28,8	16,5	743	60
221-15-4	93	22,9	17,8	749	57
177-05	94	25,5	16,5	751	56
LSD <sub>05</sub>	-	3.1	-	-	-

319

320 Table 3 – Mean values and standard deviation of trait expression in spring durum wheat varieties  
321 (2022–2024, Akmola region)

Quality parameter	Mean	Min	Max	SD
Vegetation period, days	94,9	91,0	99,0	2,4
Yield, c/ha	23,3	16,1	28,8	3,7
Protein content, %	16,3	14,7	17,8	0,7
Net weight, g/l	745,4	690,0	780,0	25,6
Vitreousness, %	57,2	54,0	61,0	2,1

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<b>Dtr</b>	<b>1,00</b>	<b>-</b>	<b>0,23</b>	<b>0,07</b>	<b>0,14</b>	<b>0,08</b>	<b>0,25</b>
<b>VP</b>	<b>0,23</b>	<b>1,00</b>	<b>0,11</b>	<b>0,38</b>	<b>-</b>	<b>0,04</b>	<b>0,38</b>
<b>Y</b>	<b>0,07</b>	<b>0,11</b>	<b>1,00</b>	<b>0,07</b>	<b>0,48</b>	<b>-</b>	<b>0,09</b>
<b>PC</b>	<b>0,14</b>	<b>0,38</b>	<b>0,07</b>	<b>1,00</b>	<b>0,21</b>	<b>-</b>	<b>0,37</b>
<b>NW</b>	<b>0,08</b>	<b>-</b>	<b>0,04</b>	<b>0,48</b>	<b>1,00</b>	<b>-</b>	<b>0,06</b>
<b>V</b>	<b>0,25</b>	<b>0,38</b>	<b>0,09</b>	<b>0,37</b>	<b>0,06</b>	<b>1,00</b>	
	<b>Dtr</b>	<b>VP</b>	<b>Y</b>	<b>PC</b>	<b>NW</b>	<b>V</b>	

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324 Note: Dtr – Disease Type of reaction, Vp - Vegetation period, Y – Yield, PC – protein content, NW - Net weight, V - Vitreousness

325 **Figure 2.** Correlation matrix of key agronomic traits (average data)

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