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Effect of planting pattern and fertilization levels on light interception, chlorophyll content and productivity of babycorn

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Abstract
A field experiment was conducted in sandy loam soils of Tamil Nadu Agricultural University, Coimbatore, during *Rabi* and summer seasons of 2016-17 and 2017-18 to evaluate the influence of crop geometry and fertilizer levels on light interception, chlorophyll content and yield of babycorn. Experiment was conducted with five crop geometry levels *viz.*, 60 × 20cm (S_1), 60 × 15cm (S_2), 45 × 20cm (S_3), 45 × 15cm (S_4), 30 × 30cm (S_5) in main-plot and four nutrient levels such as 100% recommended dose of nitrogen (RDN) (N_1), 100% RDN *fb* $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS (N_2), 125% RDN (N_3), 125% RDN *fb* $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS (N_4) in sub-plot in split-plot design. Results revealed that significantly higher light interception and babycorn yield was recorded in combination of S_4N_4 compared to others. Higher chlorophyll content was noted with N_4 without changing its values due to crop geometry levels. Hence, for better production, babycorn must be grown at S_4N_4 combination.

Keywords: Babycorn, crop geometry, nutrient levels, light interception, chlorophyll (SPAD), yield

Introduction
Babycorn (*Zea mays* L.) is an immatured, dehusked and unfertilized maize ear, harvested within two days of silk emergence but prior to fertilization (Ramchandrappa *et al.*, 2004) [10]. It is a new economic product of maize. Change in food habit from non-vegetarian to vegetarian aggravated the consumption of vegetables especially babycorn (Thavaprakaash, 2003) [18]. It was enormously successful in countries like Thailand, Taiwan, Srilanka and Myanmar. Cultivation of babycorn in India is of recent development. Its cultivation is increasing in Meghalaya, Uttar Pradesh, Haryana, Maharashtra, Karnataka and Andhra Pradesh. In India, it occupied an area of 8.5 m ha with the production and productivity of 21.3 m t and 2507 kg ha^{-1}, respectively (Anonymous, 2011).
Space available to the individual plant is necessary to use the soil resources effectively and to harvest the maximum possible solar radiation to attain higher yield (Thavaprakaash *et al.*, 2005) [19]. Babycorn ends its life cycle within 75 days and enters its reproductive phase during 50-55 DAS. Natural resources *viz.*, space, light, nutrients, moisture are underutilized. Though the earlier studies (Thavaprakaash *et al.*, 2005, Rathika, 2008) [19, 11] were tried with lesser population, considering the facts that babycorn is a short duration crop and only the immature cobs are being harvested, there is a chance of better performance under higher population.
Nitrogen is the most important nutrient for maize production (Sanjeev *et al.*, 1997) [14] and application of varied levels had significant influence on growth and yield of babycorn (Thakur *et al.*, 1997) [16]. Iron is an important micronutrient especially for cereals, wherein, the deficiency symptom is expressed as interveinal chlorosis. Iron deficiency is a well-documented problem in cultivated soils and seriously disturbs yield and nutritional quality of crops, particularly in alkaline soils (Aciksoz *at al.*, 2014) [2]. Foliar fertilization could maintain a good nutrient status when the availability of soil nutrients is limited. Also, there are barely any studies on the combination of nitrogen and foliar spraying of Fe.
Proper crop geometry and nutrient management is essential for the efficient utilization of resources in order to obtain a higher yield. Hence, the present study has been contemplated.

Material and Methods

The experiment was conducted at Eastern block farm, Tamil Nadu Agricultural University, Coimbatore during *Rabi* and summer seasons of 2016-17 and 2017-18. The experiment was laid out in split plot design with three replications. Main-plots consisted of five levels of crop geometry *viz.,* 60 × 20cm (S_1), 60 × 15cm (S_2), 45 × 20cm (S_3), 45 × 15cm (S_4), 30 × 30cm (S_5) and four levels of nitrogen and Fe nutrition such as 100% recommended dose of nitrogen (RDN) (N_1), 100% RDN *fb* $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS (N_2), 125% RDN (N_3), 125% RDN *fb* $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS (N_4) were allocated to the sub-plots. The soil of the experimental field was sandy clay loam in texture having 7.6 pH, EC of 0.45 dS m^{-1}, organic carbon of 0.35%, low in available nitrogen (233 kg ha^{-1}), medium in available phosphorus (14.20 kg ha^{-1}) and high in potassium (406 kg ha^{-1}).

The experimental field was prepared by ploughing, removing weeds, roots, stubbles, etc. and 2-3 cross harrowing. Farm yard manure (FYM) @ 12.5 t/ha was incorporated in the soil at the time of last harrowing. The sowing of babycorn into the soil @ one seed per hill at a depth of 2 to 3 cm was done as per the treatments. The recommended dose of nitrogen (RDN: 150 kg ha^{-1}), phosphorus (60 kg ha^{-1}) and potassium (40 kg ha^{-1}) in the form of urea, single super phosphate and muriate of potash, respectively were applied uniformly as per the treatments. N and K were applied in two equal splits *i.e.,* one at the time of sowing and the other at 25 days after sowing. Full dose of P was applied as basal. $FeSO_4$ foliar spray @ 1% was given at 30 and 45 DAS. All the other package of practices were carried out as per the crop schedule, mentioned in the book “Crop Production Techniques of Horticultural Crops”, 2013, by Horticultural College and Reasearch Institute, TNAU, Coimbatore.

Light interception

The measurement of light was done between 1200 and 1300 hours of the day using a quantum meter (LICOR Model LI - 185 A) with 1 m line quantum sensor. In each plot, the light incident of above the canopy was measured by holding the sensor above the crop canopy. Light transmitted through the crop canopy was measured by holding the sensor below the crop canopy. For transmitted light, two observations were taken, one holding the sensor along the row and another across the rows and the mean was taken. The percentage of light intercepted by the crop canopies was calculated as follows.

$$PLI = \frac{(LI - LT)}{LI} \times 100$$

Where,

PLI - Percentage of light intercepted,

LI - Light incident above the crop canopies and

LT - Light transmitted below the crop canopies.

Chlorophyll content

Amount of chlorophyll present in leaves was measured by non destructive method of using SPAD-502 Chlorophyll meter [Soil-Plant Analysis Development (SPAD) Section, Minolta Camera Co., Ltd, Japan]. Readings were recorded at 25 and 45 DAS with the SPAD at the fifth corn leaf downwards. Evaluations were carried out in five plants per plot, being three readings by leaves.

Green cob yield

Green cobs from plants in net plots of different treatments from all the three replications were harvested and the fresh weight of green cobs from the tagged plants was taken and expressed as kilogram per hectare. Harvesting was done in several pickings with an interval of 3-4 days. The number of pickings varied with the season wherein up to four pickings was done during *rabi* and three pickings during summer seasons.

Statistical analysis

The data were analyzed statistically following the procedure given by Gomez and Gomez (1984) [7]. Wherever the treatmental differences were significant, critical differences were calculated at five per cent probability level for comparison. Non-significant effects are indicated as NS.

Results and Discussion

Light interception

During the field investigation, light interception (LI) had steadily increased from 25 to 45 DAS. Higher light interception was recorded during *rabi* seasons compared to the summer seasons (Table 1).

Crop geometry did exhibit a perceptible difference on light interception. The light interception increased with the increase in the plant population. Light interception was more (from 54.1 to 91.1% during 25 to 45 DAS) in narrowly spaced babycorn (45 × 15cm) than the other widely spaced babycorn during *rabi* 2006. The similar trend was manifested during the other seasons also. Higher LI noted in 45 × 15cm was mainly due to higher plant population, which had produced greener biomass and leaf surface (area) per unit area in the present study and in turn intercepted more light. Aftab *et al.* (2004) [1] also reported a linear relationship between total biomass production and intercepted PAR.

During the course of investigation, nutrient levels had an appreciable influence on light interception at 25 DAS and 45 DAS. Light interception increased with increase in nutrient level and recorded a higher percentage (44.8, 41.8, 32.7 and 28.1% during 25 DAS and 81.3, 72.7, 72.0 and 62.4 during 45 DAS in *rabi* 2016, *rabi* 2017, summer 2017 and summer 2018 seasons, respectively) with the application of 125% RDN followed by $FeSO_4$ foliar spray @ 1% at 30 and45 DAS (N_4) and remained statistically on par with N_3 (125% RDN) and N_2 (100% RDN + $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS) in all the seasons. Lower light interception was recorded with N_1 (100% RDN). Increased nutrients (N and Fe) increased the LAI as evidenced in the present study which in turn had increased the LI. Similar findings were also reported by Tohidi *et al.* (2012) [20] who opined that N fertilizer is one of the main factor on plant canopy holding and light absorption on plant population. The above results also imply the effect of foliar spray of iron on light interception in the presence of nitrogen fertilization over no Fe spray, which however remained on par with higher doses of N. Application of micronutrients like Fe is known to improve the leaf area and chlorophyll content of leaf in cereals (Farhan and Al-Dulaemi, 2011) [6]. Thus improvement in leaf area indirectly contributes to increased light interception.

Table 1: Light interception as influenced by crop geometry, nitrogen and iron nutrition in babycorn

	Rabi 2016											
	25 DAS						45 DAS					
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**Mean**
N_1	32.5	39.8	41.1	51.1	41.1	41.1	63.8	75.8	76.0	89.4	76.0	76.2
N_2	34.0	42.2	43.0	54.2	44.0	43.5	64.6	79.6	78.8	90.3	81.3	78.9
N_3	34.2	43.3	43.5	55.1	45.3	44.3	65.5	81.3	79.8	92.0	82.8	80.2
N_4	34.4	43.9	44.8	56.0	44.8	44.8	65.7	82.2	82.6	92.5	83.7	81.3
Mean	33.8	42.3	43.1	54.1	43.8		64.9	79.7	79.3	91.1	80.9	
	S	**N**		**S at N**		**N at S**	**S**	**N**		**S at N**		**N at S**
SEd	0.7	0.7		1.5		1.5	1.1	1.2		2.8		2.6
CD (P = 0.05)	1.6	1.4		3.1		3.2	2.6	2.5		5.7		5.3
	Rabi 2017											
	25 DAS						45 DAS					
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**Mean**
N_1	29.9	37.5	37.6	48.2	38.3	38.3	59.0	66.1	66.4	78.9	68.6	67.8
N_2	31.2	39.9	40.2	50.3	41.9	40.7	61.2	71.0	71.0	79.9	71.2	70.9
N_3	31.3	41.5	41.2	51.5	42.5	41.6	61.5	71.6	72.6	83.9	72.9	72.5
N_4	31.7	42.0	40.4	52.2	42.8	41.8	61.7	73.0	71.1	84.3	73.1	72.7
Mean	31.0	40.2	39.9	50.5	41.4		60.9	70.4	70.3	81.8	71.5	
	S	**N**		**S at N**		**N at S**	**S**	**N**		**S at N**		**N at S**
SEd	0.7	0.6		1.4		1.6	0.9	1.2		2.7		2.1
CD (P = 0.05)	1.6	1.2		2.8		3.3	2.0	2.5		5.5		4.3
	Summer 2017											
	25 DAS						45 DAS					
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**Mean**
N_1	25.6	29.2	29.7	37.3	29.5	30.2	56.8	67.5	67.2	80.8	67.9	68.0
N_2	26.0	32.4	31.4	38.9	32.4	32.2	57.8	72.0	70.6	85.0	72.0	71.5
N_3	26.2	31.6	30.8	40.3	32.2	32.2	59.1	71.0	69.8	86.9	71.8	71.7
N_4	26.4	31.9	31.8	40.5	32.7	32.7	58.0	71.4	71.2	87.1	72.5	72.0
Mean	26.1	31.3	30.9	39.3	31.7		57.9	70.5	69.7	85.0	71.0	
	S	**N**		**S at N**		**N at S**	**S**	**N**		**S at N**		**N at S**
SEd	0.6	0.5		1.2		1.3	0.6	1.4		3.2		1.6
CD (P = 0.05)	1.3	1.1		2.4		2.6	1.4	2.9		6.6		3.3
	Summer 2018											
	25 DAS						45 DAS					
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**Mean**
N_1	19.2	25.3	25.2	32.8	25.8	25.7	49.2	59.5	57.7	67.4	59.2	58.6
N_2	20.5	27.0	27.4	34.2	27.7	27.4	52.3	60.5	61.5	71.2	62.1	61.5
N_3	20.7	27.7	27.7	33.6	28.2	27.6	52.6	62.1	62.1	71.5	63.3	62.3
N_4	20.9	27.9	28.5	34.7	28.6	28.1	52.7	62.2	62.2	71.8	63.0	62.4
Mean	20.3	27.0	27.2	33.8	27.6		51.7	61.1	60.9	70.4	61.9	
	S	**N**		**S at N**		**N at S**	**S**	**N**		**S at N**		**N at S**
SEd	0.4	0.4		1.0		0.9	0.8	1.1		2.4		1.9
CD (P = 0.05)	0.9	0.9		2.0		1.9	1.8	2.2		4.9		3.8

Interaction effect had a positive influence on light interception at both the stages in all the seasons of the study. Higher light interception (56.0, 52.2, 40.5 and 34.7 per cent at 25 DAS during *rabi* 2016, *rabi* 2017, summer 2017 and summer 2018 seasons, respectively) was observed with the treatment combination S_4N_4 (45 × 15cm spacing and application of 125% RDN followed by $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS) and was on par with S_4N_3 and S_4N_2 during both the years of *rabi*; and S_4N_3, S_4N_2 and S_4N_1 during both the summer seasons under study, while light interception was found to be lower with S_1N_1 which in turn remained statistically on par with S_1N_2, S_1N_3 and S_1N_4. Similar results were obtained at 45 DAS also. Higher population in narrowly spaced babycorn and increase in the fertilization, especially N, contributed to increased cell elongation, leaf area index which have ultimately increased light interception. The above results are in conformity with those reports of Toler *et al.* (1999) [21], Khan *et al.,* 2008 [8], Tajul *et al.,* 2013 [15].

Chlorophyll (SPAD value)

The mean data related to effect of variables on the chlorophyll (SPAD value) content of babycorn at 25 and 45 DAS are presented in Table 2.

There was no significant response on chlorophyll content due to crop geometry during the course of study except during *rabi* 2016 at 45 DAS wherein babycorn sown at 60 × 20cm recorded higher SPAD value (55.3) and was comparable with S_2 (60 × 15cm), S_3 (45 × 20cm) There was no significant response on chlorophyll content due to crop geometry during the course of study, except during *rabi* 2016 at 45 DAS wherein babycorn sown at 60 × 20cm recorded higher SPAD value (55.3) and was comparable with S_2 (60 × 15cm), S_3 (45 × 20cm) and S_5 (30 × 30cm), while S_4 (45 × 15cm) registered a lower SPAD value (49.0) and was on par with S_5 (30 × 30cm). Chlorophyll is a pigment which may not have any relationship with the plant population which might be the reason for the non significant results. However, on contrary Tajul *et al.* (2013) [12] reported significant response of SPAD values due to plant densities. Similar findings were recorded by Rathika (2008) [11].

Table 2: Chlorophyll content (SPAD) as influenced by crop geometry, nitrogen and iron nutrition in babycorn

Treatments	Chlorophyll content (SPAD)							
	Rabi				Summer			
Crop geometry	2016		2017		2017		2018	
	25 DAS	45 DAS	25 DAS	45 DAS	25 DAS	45 DAS	25 DAS	45 DAS
S_1 : 60 cm × 20 cm	53.3	55.3	39.1	48.3	44.4	50.3	42.1	43.0
S_2 : 60 cm × 15 cm	51.9	54.4	37.4	46.3	43.2	48.1	39.2	42.1
S_3 : 45 cm × 20 cm	51.2	52.8	37.0	45.8	42.8	49.4	39.4	41.6
S_4 : 45 cm × 15 cm	50.2	49.0	36.7	45.1	41.9	46.6	39.4	42.2
S_5 : 30 cm × 30 cm	52.5	52.5	37.0	45.4	42.7	48.8	39.9	41.5
SEd	1.3	1.5	1.3	1.4	1.3	1.7	1.4	0.8
C.D. (P=0.05)	NS	3.6	NS	3.2	NS	NS	NS	NS
N and Fe nutrition								
N_1 : 100% RDN	49.2	50.5	35.5	44.3	40.7	46.4	38.0	39.1
N_2 : 100% RDN + $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS	52.7	52.7	37.2	46.0	43.0	48.0	39.2	42.5
N_3 : 125% RDN	53.2	53.5	38.2	46.8	44.0	49.4	40.2	43.0
N_4 : 125% RDN + $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS	54.2	54.4	39.8	48.6	45.2	50.7	41.5	45.1
SEd	1.1	1.8	1.4	1.3	1.3	1.6	1.2	1.5
C.D. (P = 0.05)	2.2	3.6	2.9	2.7	2.7	3.2	2.5	3.0
Interaction is absent								

Nutrient treatments showed a significant influence on the chlorophyll content of babycorn at 25 and 45 DAS in all the seasons of study. During *rabi* 2016, higher chlorophyll content (SPAD value) of 54.2 and 54.4 was observed with the application of 125% RDN followed by $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS) at 25 and 45 DAS, respectively and was comparable with higher dose of N application N_3 (125% RDN) and lower dose of N application along with Fe N_2 (100% RDN followed by $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS) while lower content of chlorophyll (49.2 and 50.5 at 25 and 45 DAS, respectively) was noted with lower N level N_1 (100% RDN). The results were similar during the other seasons also. Similar results were observed by Tajul *et al.* (2013) [15] who stated that the relationship between SPAD values and N-content was linearly associated at different growth stages and 50 to 62 per cent N-content variation in maize leaves can be attributed to the difference in SPAD values. The significant difference in SPAD values between N_1 (100% RDN) and N_2 (100% RDN followed by $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS) *i.e.* no iron and iron application, show the role of Fe in improving the chlorophyll content. However, it remained on par at higher dose of N. Iron plays an important role in biosynthesis of chlorophyll, chloroplast development and photosynthesis and when applied as foliar spray it resulted in quick absorption by the leaf epidermis of the plant. Thus iron might have enhanced the chlorophyll content of the leaf. Similar findings were reported by Rawashdeh and Sala (2014) [12] who observed that foliar application of Fe at different growth stages of wheat significantly increased and improved the flag leaf area and flag leaf chlorophyll content as compared to without Fe application.

The interaction effect was found to be non significant during the course of study.

Table 3: Green cob yield (kg/ha) of babycorn as influenced by crop geometry, nitrogen and iron nutrition in babycorn

Treatments	*Rabi* 2016						*Rabi* 2017					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
N_1	5631	7021	7052	9160	7208	7214	4953	6381	6514	8377	6656	6576
N_2	5716	7433	7132	9057	7167	7301	5020	6428	6400	8545	6667	6612
N_3	5664	7281	7261	9822	7782	7562	5112	6466	6711	9008	6925	6844
N_4	5705	7393	7471	10100	7729	7680	5066	7050	6628	9148	7064	6991
Mean	5679	7282	7229	9535	7472		5038	6581	6563	8770	6828	

	Rabi 2016				*Rabi* 2017			
	S	N	S at N	N at S	S	N	S at N	N at S
SEd	270	233	521	608	271	218	488	608
C.D (P=0.05)	622	NS	1063	1261	624	NS	997	1262

Treatments	Summer 2017						Summer 2018					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
N_1	4856	5982	5996	7099	5944	5975	3849	5051	5048	6277	5197	5084
N_2	5036	6111	5915	7148	5909	6024	3900	5060	5087	6271	5155	5095
N_3	5145	6065	6055	7277	6331	6175	4145	5057	5173	6394	5269	5208
N_4	5579	6203	6069	7297	6354	6300	4141	5283	5210	6491	5333	5292
Mean	5154	6090	6009	7205	6135		4009	5113	5130	6358	5239	

	Summer 2017				Summer 2018			
	S	N	S at N	N at S	S	N	S at N	N at S
SEd	131	214	479	316	191	191	428	435
C.D (P=0.05)	303	NS	977	649	441	NS	874	899

Green cob yield

Babycorn raised at 45 × 15cm (S_4) produced a higher cob yield (9535, 8770, 7205 and 6358 kg/ha during *rabi* 2016, *rabi* 2017, summer 2017 and summer 2018 seasons, respectively) over the other crop geometry levels and S_1 (60 × 20cm) recorded a lower cob yield, regardless of the season (Table 3). Babycorn is short lived and end product is an immature cob which may not require wider spacing like grain maize which is generally double the duration of babycorn and allowed for maturity. In the present study increase of population by closer spacing didn't harm the yield attributes such as length and girth of cob but increased the number of cobs per unit area which in turn increased the cob yield. These results are in conformity with Bairagi *et al.* (2015) [3], Chamroy *et al.* (2017) [4].

No significant difference was observed due to the nitrogen levels and iron foliar nutrition on green cob yield during the study period (Table 3). As the crop duration for babycorn is lesser and the end product is a young immature cob, higher nutrient doses might not have influenced on the cob yield. Zhang *et al.* (2010) [23] also reported that biomass and grain yield of wheat were not significantly affected by the foliar application of Fe. Similar results were reported by Thakur and Sharma (1999) [17], Rajendran and Singh (1999) [9] and Sahoo (2011) [13].

With regard to interaction, it had a positive effect on green cob yield of babycorn over seasons. Raising of babycorn at 45 × 15cm spacing together with application of 125% RDN followed by $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS (S_4N_4) recorded the significantly higher green cob yield (10100, 9148, 7297 and 6491 kg/ha during *rabi* 2016, *rabi* 2017, summer 2017 and summer 2018 seasons, respectively) and was on par with S_4N_3, S_4N_2 and S_4N_1 (Table 3). Babycorn in other words, is a short duration maize which requires a optimum plant stand to tap the resources available in a short time for increasing the yield. Thus, an optimally higher population leading to increased leaf area index, light interception and adequate fertilization in babycorn sown at narrow row spacing might have resulted in higher yield. These results are in accordance with Edwards *et al.* (2005) [5] who opined that increasing plant density for short season maize increases the cumulative intercepted PAR, which compensates for a short growing season to achieve high yields. Aftab *et al.* (2004) [1] also reported a linear relationship between total biomass production and intercepted PAR. Similar findings were observed by Venkata lakshmi *et al.* (2016) [22].

Conclusion

From the study, it was observed that babycorn raised at a spacing of 45 × 15cm along with 125% RDN followed by $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS produced higher yields over the other crop geometry levels but on par with other nutrient levels. Foliar spray of iron improved the chlorophyll content of the leaf and light interception by increasing the LAI in the presence of nitrogen fertilization which however remained on par with higher doses of N. Thus it can be concluded that for babycorn raised at an optimum spacing of 45 × 15cm along with application of 100% RDN followed by $FeSO_4$ foliar spray @ 1% at 30 and 45 DAS is optimum for obtaining higher yields in western Agroclimatic zone of Tamil Nadu.

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