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Effect of different shade net colour and intensity on yield and quality attributes of tomato (*Lycopersicon esculentum* L.) in Western Rajasthan

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Abstract
The investigations on “Effect of Different Shade Net Colour and Intensity on Yield and Quality of Tomato, (*Lycopersicon esculentum* L.) in Western Rajasthan” was conducted at Precision Farming Development Centre, Agricultural Research Station, SKRAU, Bikaner from November, 2020 to June, 2021. Different colour (Red, Black, White, and Green) shade net with varying shade intensities (35%, 50%) were found to be significantly influenced most of the yield and quality attributes of tomato.

The maximum number of flower per cluster (1.58, 1.91, 4.32, 4.66), and maximum number of fruit per cluster (1.43, 1.56, 4.04, 4.24) at 50, 75, 100,125 DAT were recorded under red colour shade net. Maximum number of fruit per plant (5.77, 9.94, 31.60, 39.20) at 50, 75, 100, 125 DAT were recorded under red colour shade net with 50% shade intensity. Maximum fruit length (5.25 cm), weight (80.90 g) and diameter (5.11 cm) were recorded under black colour shade net. Maximum fruit yield per hectare (601.33 quintal ha^{-1}) and highest B: C ratio (2.73) was recorded under red colour shade net with 50% shade intensity. Maximum TSS (4.65^0 B), acidity (0.85%), ascorbic acid (15.96 mg/100 g), lycopene (6.15 mg/100 g) and firmness (4.15 Kg cm^{-2}) were obtained in which fruits those were grown under red colour shade net.

Keywords: Tomato, shadenet colour, shade intensity and lycopene

Introduction
Vegetables are key sources of many nutrients, including potassium, dietary fiber, folate (folic acid), vitamin A, and vitamin C. Among the vegetable crops tomato (*Lycopersicon esculentum* L.) is 2nd most important vegetable crop after potato. It belongs to family Solanaceae. In India, it is grown throughout the year particularly in the vicinity of cities. Tomato is an important “protective food” because of its special nutritive value and versatile wide uses. It is eat up as ripe as well as in green stage. Green tomatoes are consumed as cooked vegetables and also used for pickles. Ripe tomatoes are used for making soup, juice, ketchup, sauce, puree, salad, chutney and many other products. It is an important crop for processing industry and canned vegetable tomato, top in the list amongst the processed products. Tomato fruits are rich source of carbohydrate (3.63 g), protein (0.9 g), vitamin A (585 IU), vitamin C (26 mg), starch (0.6-1.2%), minerals like calcium (48 mg) iron (0.4 mg) and phosphorus (0.2-0.8 g) per 100 gram of edible portion (Aykroyd, 1963) [1]. It is known as “the poor man`s orange”. It not only possesses medicinal properties but also said to be excellent blood purifier. Pulp and juice of tomato are digestible and promoter of gastric secretions. The major tomato producing states in India is Andhra Pradesh, Karnataka, Orissa, Maharashtra and W.B. In India total production of tomato is approximately 19759 thousand M T from about 789 thousand hectares. Rajasthan contributes about 88.73 thousand MT covering an area of 18.12 thousand hectares. The major tomato growing districts of Rajasthan are Jaipur, Dholpur, Alwar, Tonk, Kota, Bundi (NHB, 2018-19). Protected cultivation is a cropping technique where micro climate surrounding the plant body is controlled partially or fully as per the requirement of crops grown during their period of growth. With the advancement in horticulture various types of protected cultivation practices suitable for a specific type of agro-climatic zone have emerged. There are various types of protected cultivation practices. Some of the commonly used practices are forced ventilated greenhouse, naturally ventilated polyhouse, insect-proof net house, shade net house and mulching etc.

These practices can be used independently or in combination, to provide favorable environment to save plants from harsh climate and extend the duration of cultivation or off-season crop production. This technology can be adopted by the rural youth for more income per unit of land. The improvement in economy of farmers with the decreasing land holding is also possible through the protected cultivation by increasing production per unit area. The glut of vegetable during a short period of harvesting is also the problem in the country which can be minimized with the protected cultivation as harvesting period of crops under protected structures is longer.

Materials and Methods

A field experiment entitled "Effect of Different Shade Net Colour and Intensity on Yield and Quality of Tomato (*Lycopersicon esculentum* L.) in Western Rajasthan" was conducted at Precision Farming Development Centre, Agricultural Research Station, SKRAU, Bikaner from November, 2020 to June, 2021.The experiment was laid out at Precision Farming Development Centre, Agricultural Research Station, SKRAU, Bikaner. Geographically the farm is situated 9 km away from Bikaner at an altitude of 234.7 m above mean sea level and latitude of 28°01'N and longitude of 73°22'E. According to "Agro ecological region map" brought by National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Bikaner falls under Agro ecological region No.2 (MgE1) under arid ecosystem (hot Arid Eco-region with desert and Saline soils), which is characterized by deep, sandy and coarse loamy, desert soils with low water holding capacity, hot and arid climate, precipitation less than 300 mm. PET in this region ranges between 1500 to 2000 mm. As per NARP, Bikaner falls in Agro climatic zone (lC) which has been carved out of the original agro-climate zone (lA). The newly created zone lC is known as Hyper Arid Partially Irrigated North Western Plain Zone (IC). According to National Planning Commission, Bikaner falls under Agro climatic zone XIV (western Dry Region) of India. Bikaner district extends from 27°15' to 29°5' north latitude and 71°54' to 74°12' east longitudes. Bikaner has arid climate with an annual average rainfall of about 260 mm, more than 80% rainfall is received in the south-west monsoon season. During summer, the maximum temperature may go as high as 48°C while it may fall as low as 0°C.This region is prone to be high wind velocity and soil erosion. Soil drifting due to high speed wind leads to soil erosion is the major problem in the summer. The soils in the arid region are sandy to sandy loam with low fertility and productivity level. The experimental design was laid out into split plot design and comprised of 8 treatments. For colour (Red, Black, White, and Green) of shade net were taken in main plot and two shade intensities (35%, 50%) were taken in sub plot. Number of flower was counted from cluster of five sample plant at regular interval at 50,75,100,125 DAT and average was done to record number of flower per cluster. Number of cluster was counted from five sample plant at regular interval at 50, 75,100,125 DAT and average was done to record number of cluster per plant. Number of fruits was counted from cluster of five sample plant at regular interval at 50,75,100,125 DAT and average was done to record number of fruit per cluster. Number of fruits was counted from five sample plant at regular interval at 50, 75,100,125 DAT and average was done to record number of fruit per plant.

Five selected fruits were measured for fruit length (cm) with the help of Vernier calipers from each replication of each treatment and the average was calculated. The weights of five fresh fruits harvested randomly from selected plants were taken during harvesting and average weight of fruit was calculated and expressed in g per fruit. Five selected fruits were measured for fruit diameter (cm) with the help of vernier calipers and the average was calculated. The weight of fruits harvested in each treatment was measured and yield per treatment was converted to yield quintal per hectare. The cost of cultivation of tomato under different coloured shade net house conditions was worked out by considering the present price of inputs and the labour cost that were prevailing at the time of their use. Gross returns, benefit cost ratio were worked out for each treatment by adopting the following formula-

$$\text{Benefit/Cost ratio} = \frac{Gross\ returns\ (Rs\ ha-1)}{Cost\ of\ cultivation\ (Rs.ha-1)}$$

Five fruits were randomly selected to determine to total soluble solids (%) from each treatment (every replication) and washed with the water. The fruits were cut into small pieces and squeeze to obtain the juice and with the help of digital refractometer TSS (%) of fruits was determined. The average was calculated and average was expressed as percent total soluble solids in juice.

The titrable acidity was measured from pulp of fruit. For this, seeds were removed and pulp was separated out and mixed to prepared pooled sample for each replication. For extraction of juice, one gram of pooled pulp was macerated with 25 ml distilled water and the whole mesh was filtered through the muslin cloth. 10 ml of this, fruit juice was titrated against N/10 Sodium Hydroxide (NaOH), using Phenolphthalein as an indicator. The present acidity was calculating using the formula (A.O.A.C., 2007).

$$\text{Acidity (\%)} = \left(\frac{d \times 0.064 \times c}{a \times b}\right) \times 100$$

Where,
a = weight of sample
b = Volume of aliquot taken for examination
c = Volume made with distilled water
d = Average burette reading for sample

Ascorbic acid (mg 100^{-1} g pulp)
Reagents
Met phosphoric acid (HPO_3) solution (3%)
Dye solution: 50 mg of 2, 6-dichlorophenol-indophenol was dissolved in 150 ml of hot distilled water containing 42 mg of sodium bicarbonate. It was cooled and diluted with distilled water to 200 ml. The solution was stored in brown bottle in a refrigerator at about 3 °C.

Standard Ascorbic acid solution: 100 mg of L-ascorbic acid was dissolved in a small volume of 3% metaphosphoric acid solution and volume was made up to 100 ml with 3% metaphosphoric acid (0.1 mg ascorbic acid per ml).

Procedure

Standardization of dye: 5 ml of standard ascorbic acid solution was diluted with 5 ml of 3% metaphosphoric acid. This was titrated with dye solution till pink color persists for 10 seconds. Calculated the dye factor (mg of ascorbic acid per ml of dye) as follows.

Dye factor (D.F.) = 0.5/titter

Preparation of the sample and titration

10 g sample was diluted to 100 ml with 3% metaphosphoric acid and filtered. It 10 ml of filtrate was pipetted into a conical flask and titrated with the standard dye to a pink end-point.

Calculation

Ascorbic acid (mg/100 g) = $\left(\frac{a\times b}{c\times d}\right)\times 100$

Where,

a = Titre x Dye factor

b = Volume made up

c = Volume of filtrate taken

d = weight or volume of sample take

Absorption determination for lycopene content was made by using Spectrophotometer. Lycopene in the tomato samples was extracted with hexane: ethanol: acetone (2:1:1) (v/v) mixture following the method of Sharma and Le Maquer.

One gram of the homogenized samples and 25 ml of hexane: ethanol: acetone, which was then placed on the rotary mixer for 30 min., adding 10 ml distilled water and was continued agitation for another 2 min. The solution was then left to separate into distinct polar and non-polar layers. The absorbance was measured at 472 nm and 502 nm, using hexane as a blank. The lycopene concentration was calculated using its specific extinction coefficient (E 1%, 1 cm) of 3450 in hexane at 472 nm and 3150 at 502 nm. The lycopene concentration was expressed as mg/100 g product. All determinations were repeated for three times.

$$\text{At } \lambda = 472nm\text{: } lycopene\ content\ (mg/100g) = E/345 \times 20/m$$

$$\text{At } \lambda = 502nm\text{: } lycopene\ content\ (mg/100g) = E/315 \times 2$$

Whereas m= the weight of the product (g); E-extinction coefficient

Firmness was determined by using fruit penetrometer. Five ripened fruits of each treatment were punctured at one place in radial axis with plunger and pressure required to penetrate the fruit was recorded and expressed in kg/cm$^{2.}$

Results and Discussion

Number of flowers per cluster of tomato plant was significantly influenced by colour of shade net during whole growth period. Significantly maximum number of flower per cluster (1.58, 1.91, 4.32, 4.66) noted under red colour shade net at 50, 75,100,125 DAT respectively. This could be attributed to favorable climatic condition coupled sufficient photosynthates accumulation. Similar finding were recorded by Leite *et al.* (2008) [8] on phalaenopsis.

Effect of shade net colour and shade intensity on number of cluster per plant was observed during whole growth period. Effect of shade net colour and shade intensity on number of cluster per plant at all growth stage found non-significant. This was possibly due to number of cluster per plant controlled by genetic factor.

The maximum number of fruit per cluster (1.43, 1.56, 4.04, 4.24) at 50, 75,100,125 days after transplanting was noted under red shade net. This could be attributed to higher number of flowers per cluster, lesser flower drop, greater extent of fruit set leading to more number of fruits per cluster. Similar result noted by Llic *et al.* (2015) [9] on tomato.

Number of fruit per plant was significantly affected by shade net colour, intensity of shade and interaction between shade net colour and intensity of shade net during whole growth period. Maximum number of fruit per plant (5.77, 17.94, 31.60, 39.20) at 50, 75, 100, 125 DAT respectively was noted under red colour shade net coupled with 50% shade intensity because of greater extent of fruit set leading to more number of fruits per plant. This was in agreement with Retamales *et al.* (2008) [12] in blue berries and Chauhan *et al.* (2018) [2] on tomato.

Fruit length was significantly influenced by different colour of shade net. Maximum fruit length (5.25 cm) was observed in black colour shade net. This could be due to high uptake of nutrients and build of sufficient photosynthates, enabling the increase in size of fruits. These findings also reported by Hasanein *et al.*(2011) [6] in strawberry and Godi *et al.* (2018) [5] in tomato.

Fruit weight was significantly influenced by different colour of shade net. Maximum fruit weight (80.90 g) was observed in black colour shade net. This could be due to high uptake of nutrients and build of sufficient photosynthates and less number of fruit so fruit get deposited more photosynthetate enabling the increase in size of fruits. Most equal results were reported by Chauhan *et al.* (2018) [2] in strawberry and Godi *et al.* (2018) [5] in tomato.

Fruit diameter was significantly influenced by different colour of shade net. Maximum fruit diameter (5.11 cm) was observed in black colour shade net because of high uptake of nutrients and build of sufficient photosynthates, enabling the increase in size of fruits. This finding is in agreement with Hasanein *et al.* (2011) [6] in strawberry and Godi *et al.* (2018) [5] in tomato.

Maximum fruit yield (548.33 quintal ha^{-1}) was noted under red shade net. This is due to the higher yield per plant which is directly related to higher yield per hectare. Similar results were find out by Llic *et al.* (2011) [10] in capsicum.

The perusal of data showed that fruit yield quintal ha^{-1}) significantly influenced by shade intensity. The maximum tomato fruit yield (508.662q ha^{-1}) was recorded under 50% shade. Similar results were recorded by Chauhan *et al.* (2018) [2] in tomato.

The data subjected to statistical analysis manifested that the two-way interaction effects between red shade net and 50% shade intensity found to be highly significant over other treatments. Maximum fruit yield (601.33q ha^{-1}) was obtained under red colour shade net with 50% shade intensity. This was agreement with Godi *et al.* (2018) [5]

Maximum B: C ratio (2.73) was observed in red shade net with 50% shade intensities. Higher yield of excellent fruit quality, fetching better price in the market has resulted in getting higher B: C ratio.

The result revealed that TSS of fruit was significantly influenced by different colour of shade net. Maximum TSS was noted in red colour shade net (4.65^0 B). This might be due to quality light gain by red shade net which might have enhanced the production of total soluble solids. Similar results were find out by Davies and hobson (1981) [3] in tomato and Godi *et al.* (2018) [5].

Acidity of fruit was significantly influenced by different colour of shade net. Maximum acidity was observed in red colour shade net (0.85%). This could be due to increase in total irradiance and quality light resulting in enhancement of total acid content. The findings were agreement with studies conducted by Llic *et al.* (2012) [7] on tomato.

Acid content was maximum (15.96 mg/100 g) under red shade net. This might be due to increase in total irradiance resulting in enhancement of ascorbic acid content. Similar results were find out by Godi *et al.* (2018) [5] in tomato, Sahak *et al.* (2007) [13] on bell peper and Davies and Hobson (1981) [3] in tomato.

Lycopene content was found maximum (6.15 mg/100 g) in which fruits that were grown under red shade net. This was attributed to the light intensity received by the plant which was optimum for enhancement of colour development of the pericarp and optimum solar radiation which might have lead to production of more lycopene content. Similar results were find out by studies conducted by Rai *et al.* (1995) [14] on capsicum, Dissnayak *et al.* (2020) [4] on tomato and Llic *et al.* (2012) [7] on tomato. Significantly higher value of firmness found under red shade net and it was 4.15 kg/cm^2. This might be because of quality of light that plant get, leading to thick cell wall formation and a lesser influx of water into the cells make the thick rind. Similar results were found by Hasanein *et al.* (2011) [6] in strawberry and Godi *et al.* (2018) [5] on tomato.

Table 1: Effect of different shade net colour and intensity on number of flowers per cluster of tomato

Treatments	**Number of flower per cluster**			
	50 DAT	**75 DAT**	**100 DAT**	**125 DAT**
Shade net colour (C)				
C_1 – Red	1.58	1.91	4.32	4.66
C_2 – Black	1.21	1.45	3.47	3.87
C_3 – white	1.31	1.49	3.68	4.08
C_4 – Green	1.47	1.73	3.89	4.48
S.Em±	0.06	0.07	0.10	0.16
C.D at 5%	0.21	0.26	0.33	0.56
Shade Intensity(I)				
I_1 – 35%	1.34	1.60	3.74	4.19
I_2 _ 50%	1.44	1.69	3.93	4.35
S.Em±	0.04	0.05	0.07	0.05
C.D at 5%	NS	NS	NS	NS

Table 2: Effect of different shade net colour and intensity on number of cluster per plant of tomato

Treatments	**Number of cluster per plant**			
	50 DAT	**75 DAT**	**100 DAT**	**125 DAT**
Shade net colour(C)				
C_1 – Red	4.02	6.00	8.65	8.45
C_2 – Black	3.76	5.48	8.18	7.73
C_3 – white	3.94	5.60	8.13	8.65
C_4 – Green	3.93	5.37	8.38	8
S.Em±	0.06	0.20	0.11	0.21
C.D at 5%	NS	NS	NS	NS
Shade Intensity(I)				
I_1 - 35%	3.89	5.50	8.24	8.08
I_2 - 50%	3.94	5.73	8.43	8.34
S.Em±	0.05	0.08	0.09	0.13
C.D at 5%	NS	NS	NS	NS

Table 3: Effect of different shade net colour and shade intensity on number of fruit per cluster of tomato

Treatments	**Number of fruit per cluster**			
	50 DAT	**75 DAT**	**100 DAT**	**125 DAT**
Shade net colour(C)				
C_1 – Red	1.43	1.56	4.04	4.24
C_2 – Black	1.16	1.33	3.21	3.47
C_3 – white	1.28	1.35	3.43	3.60
C_4 – Green	1.37	1.41	3.65	3.66
S.Em±	0.05	0.03	0.14	0.13
C.D at 5%	0.17	0.10	0.49	0.46
Shade Intensity(I)				
I_1 – 35%	1.26	1.34	3.47	3.62
I_2 _ 50%	1.36	1.48	3.69	3.86
S.Em±	0.02	0.04	0.07	0.07
C.D at 5%	0.07	0.14	0.22	0.23

Table 4: Effect of different shade net colour and intensity on number of fruit per plant

Treatments	Number of fruit per plant			
	50 DAT	75 DAT	100 DAT	125 DAT
Shade net colour (C)				
C_1 – Red	5.44	15.15	29.27	36.67
C_2 – Black	2.42	7.63	18.62	24.52
C_3 – white	3.45	9.10	21.62	28.17
C_4 – Green	4.24	12.53	27.30	35.59
S.Em±	0.10	0.48	0.18	0.46
C.D at 5%	0.35	1.68	0.62	1.60
Shade Intensity (I)				
I_1 - 35%	3.69	9.50	22.74	29.99
I_2 - 50%	4.08	12.71	25.66	32.52
S.Em±	0.08	0.41	0.17	0.32
C.D at 5%	0.27	1.33	0.54	1.04

Interaction Effect on fruit per plant at 50 DAT					
Colour of shade net					
Shade intensity	**C_1**	**C_2**	**C_3**	**C_4**	**Mean**
I_1 - 35%	5.12	1.82	4.68	3.15	3.69
I_2 - 50%	5.77	3.20	3.79	3.75	4.08
Mean	5.44	2.42	4.24	3.45	
S.Em± CD at 5% C at the same level of I 0.15 0.50 I at the same level of C 0.16 0.53					
Interaction Effect on fruit per plant at 75 DAT					
Colour of shade net					
Shade intensity	**C_1**	**C_2**	**C_3**	**C_4**	**Mean**
I_1 - 35%	12.37	7.31	8.83	8.83	9.50
I_2 - 50%	17.94	7.69	9.37	9.37	12.71
Mean	15.15	7.63	9.10	9.10	
S.Em± CD at 5% C at the same level of I 0.28 0.90 I at the same level of C 0.16 0.54					

Interaction Effect on fruit per plant at 100 DAT					
Colour of shade net					
Shade intensity	**C_1**	**C_2**	**C_3**	**C_4**	**Mean**
I_1 - 35%	26.95	16.57	20.28	27.15	22.74
I_2 - 50%	31.60	20.68	22.90	27.45	25.66
Mean	29.27	18.62	21.59	27.30	
S.Em± CD at 5% C at the same level of I 0.30 0.96 I at the same level of C 0.33 1.08					
Interaction Effect on fruit per plant at 125 DAT					
Colour of shade net					
Shade intensity	**C_1**	**C_2**	**C_3**	**C_4**	**Mean**
I_1 - 35%	34.28	22.85	28.01	34.83	29.99
I_2 - 50%	39.20	26.19	28.33	36.34	32.52
Mean	36.74	24.52	28.17	35.59	
S.Em± CD at 5% C at the same level of I 0.65 2.11 I at the same level of C 0.64 2.08					

Table 5: Effect of different shade net colour and shade intensity on fruit length (cm), fruit weight (g) and fruit diameter (cm)

Treatment	Fruit length(cm)	Fruit weight(g)	Fruit diameter(cm)
C_1 – Red	4.74	76.10	4.27
C_2 – Black	5.25	80.90	5.11
C_3 – white	5.15	77.83	4.92
C_4 – Green	4.44	72.00	3.75
S.Em±	0.13	1.70	0.11
CD at 5%	0.46	5.87	0.39
Shade intensity			
I_1 – 35%	4.71	75.63	4.43
I_2 _ 50%	5.08	77.78	4.59
S.Em±	0.10	1.13	0.09
CD at 5%	NS	NS	NS

Table 6: Effect of shade net colour and shade intensity on fruit yield quintal ha^{-1}

Treatment	Fruit yield quintal ha^{-1}				
C_1 – Red	548.33				
C_2 –Black	379.16				
C_3 –White	424.33				
C_4 –Green	497.04				
S.Em±	9.36				
CD at 5%	32.40				
Shade intensity					
I_1 - 35%	415.81				
I_2 - 50%	508.62				
S.Em±	4.35				
CD at 5%	14.19				
Interaction effect of shade net colour and shade intensity on fruit yield					
Shade intensity	**Colour of shade net**				
	C_1	**C_2**	**C_3**	**C_4**	**Mean**
I_1 - 35%	495.33	318.16	389.00	460.75	415.81
I_2 - 50%	601.33	440.16	459.66	533.33	
Mean	548.33	379.16	424.33	497.04	508.62
C at the same level of I		**S.Em±**		**CD at 5%**	
		11.20		36.54	
I at the same level of C		8.70		28.39	

Table 7: Effect of different shade net colour and intensity on net return and B: C ratio

Treatment	Net Return	B:C Ratio
C_1 – Red	869403.33	2.73
C_2 –Black	446486.67	1.89
C_3 –White	559403.33	2.12
C_4 –Green	741174.17	2.48
S.Em±	23411.12	0.05
CD at 5%	81013.13	0.16
Shade intensity		
I_1 - 35%	538101.25	2.07
I_2 - 50%	770132.50	2.54
S.Em±	10884.48	0.02
CD at 5%	35496.28	0.07

Table 8: Effect of different shade net colour and shade intensity on quality attributes of tomato fruit

Treatments	TSS ^{0} Brix	Acidity (%)	Ascorbic acid(mg/100 g)	Lycopene(mg/100 g)	Firmness(kg/cm^2)
Shade net colour(C)					
C_1 –Red	4.65	0.85	15.96	6.15	4.15
C_2 –Black	3.60	0.60	12.38	5.10	3.41
C_3 – white	3.85	0.68	13.83	5.75	3.75
C_4 – Green	4.16	0.76	15.65	5.82	3.95
S.Em±	0.47	0.03	0.66	0.12	0.14
C.D at 5%	0.67	0.11	2.29	0.41	0.47
Shade Intensity(I)					
I_1 – 35%	4.03	0.73	14.19	5.43	3.76
I_2_ 50%	4.10	0.71	14.72	5.98	3.87
S.Em±	0.10	0.01	0.39	0.19	0.10
C.D at 5%	NS	NS	NS	NS	NS

Summary and Conclusions

Based on one year of experimentation, it could be concluded that growing of tomato under red colour shade net with 50% shade intensities found most suitable for achieving maximum yield and monetary benefit during Rabi season. But it needs further confirmation.

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