



# Influence of Plant Population Density on Growth and Yield of Lavender (*Lavandula Angustifolia* L.) at Menagesha West Ethiopia

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**Abstract:** Field experiments were carried out during the two successive seasons of 2017 and 2018, at Menagesha Tisher rehabilitation center under supplementary irrigation condition. The aim of this investigation was to determine the effect of intra and inter-row spacing on growth and yield of lavender. Factorial combinations of four intra-rows (40, 50, 60, and 70 cm) and three inter-row plant spacing's (40cm, 60cm and 80cm) were laid out in a randomized complete block design with three replications. The Pooled mean analysis result showed that the main effect of year, intra-row and inter-row spacing, as well as their interaction, were significantly affected, the number of branches per plant, leaf yield, flower yield, above ground biomass and oil yield. However, plant height was not affected by the main effect of intra -row and inter-row spacing except the year effect. Significantly higher dry leaf yield (2.34 t ha<sup>-1</sup>), dry flower yield (0.37 t ha<sup>-1</sup>), dry flower oil yield (10.3 t ha<sup>-1</sup>) and leaf oil yield (13.9t ha<sup>-1</sup>) were obtained from the combined space of 40cm intra-row and 40 inter-row spacing. Thus the best combined intra-row and inter-row spacing for *Lavandula angustifolia* is 40cm x 40cm to attain maximum yield under appropriate management conditions for Menagesha and Similar agro ecology.

**Keywords:** *Lavandula angustifolia*, intra-row, inter -row spacing, population density

## 1. INTRODUCTION

*Lavandula angustifolia* is a small, aromatic shrub belongs to the family Lamiaceae. Most lavender originates in the Mediterranean basin, in rocky, calcareous areas and Occurs over North Africa, the Mediterranean, Europe and Western India. Lavender was cultivated by the ancient Greeks, Romans and in Elizabethan England (Adam, 2006). It is an evergreen, fast growing, compact and fragrant. The origins of its name are probably from the Latin word *Lavare* indicating the plant has another use, as it means to be washed, and suggests it was regularly used to perfume bathing water (Whiriskey and McCarthy, 2006). It produces essential oil and the parts used for essential oil distillation are the flowers and leaves. An essential oil from only the flowering tops is of higher quality than oil obtained from the leaves (Adam, 2006)

Lavender is an incredible and much sought after aromatic plant having a significant position in the perfumery trade all over the world. It has multifarious uses and market outlets. Besides its use in fragrance applications, predominantly body care products, Lavender oil has substantial applications in alternative health care practices of aromatherapy (Chatterjee, 2002).

Pure oil can be used without base oil. It has a remarkable effect on the emotional and mental balance of human beings (Chatterjee, 2002). In addition, it is used in soap making, high-quality perfumes, candles, incense sachet, as a detergent and cleaning agent, as an insect repellent, and also used in bath products such as soap, shampoo, bath oil, lotion, bath salt, repel mice. Its powerful antiseptic properties are able to kill many of the frequent bacteria, such as typhoid, diphtheria, streptococcus and pneumococcus, as well as being a powerful antidote to some snake venoms. It is very useful in the treatment of burns, sunburn, scalds and bites (Chatterjee, 2002). The essential oil is used in aromatherapy and the leaves are also added to bath water for fragrance, and their therapeutic properties (Adam, 2006).

Plant spacing is agronomical practices that determine the spatial distribution of plants which affects canopy structure, light interception and radiation use efficiency and, consequently, biomass

production of plants. Optimum plant density of variety considerably depending upon climatic condition of the growing area and fertility status of the soil is important.

Plant distant is an important factor in higher production and gives equal opportunity to plants for their survival and best use of other inputs. Spacing has critical effects on quantitative and qualitative characters of plants (Badi *et al*, 2004). To achieve the highest yield of economic production per unit area, crops should intercept solar radiation fully during the growing stage, in which photosynthesis provides carbohydrate for the economic products (Hall, 1990). In general, increasing a plant population produce a greater biological yield per unit area for most crops up to some upper limit or threshold density, after which further increase in plant density either maintain the same yield or cause yield decline. Hence it seems that plant geometry could be used as a management tool for maximizing crop growth and yield, so it is advisable to carry out trial in each plant to establish adequate plant population density. Therefore, in Ethiopia on the effect of intra-row and inter-row spacing on growth parameters, oil content and oil yield of lavender have not been yet reported. Therefore, this investigation was initiated with the objective of to determine optimum plant population density of growth and oil yield of *Lavandula angustifolia* in Ethiopia condition.

## **2. MATERIAL AND METHODS**

The experiment was carried out under supplementary irrigated condition at Menagesha Rehabilitation Center- Cheshire Ethiopia during two successive seasons of 2016/17 and 2017/18. Menagesha Rehabilitation Center-Cheshire is located 20 km west of Addis Ababa at 09°03'N latitude and 38°34' 60''E longitude with an altitude of 2812masl. The site receives a mean annual rainfall of 1056mm with minimum and maximum temperature of 6 °C and 22°C, respectively. The soil is clay with an average pH of 5.4. The experiment was conducted on *Lavandula Angustifolia* using four intra-row spacing (40cm, 50cm, 60cm and 70cm) and three inter-row spacing (40cm, 60cm and 80cm) that were laid out in a factorial randomized completely block design (RCBD) with three replications. Each treatment had a plot size of 4.20 m x 3.60 m and spaces between each plot and replication were 1m and 1.5m respectively. The number of plants per row and the number of row per plot were determined by intra and inter-row spacing respectively. Soft stem cutting with 15 cm length were taken from a one year old disease free mother plants maintained at Wondo Genet Agricultural Research Center botanical garden in seedling preparation. Seedlings were raised in the nursery for three months in polyethylene pots before transplanting to the actual field. First cycle harvesting was done seven months after transplanting, consecutively, second cycle harvestings were done at seven month intervals. During experimentation, all nursery and field agronomic practices were performed as required.

### **2.1. Data to be Collected**

Plants from the center were harvested by excluding border rows to collect yield and yield contributing characters on plant height, fresh leaf weight plant<sup>-1</sup>, number branch plant<sup>-1</sup>, flower weight plant<sup>-1</sup>, fresh stem weight, above ground biomass plant<sup>-1</sup>, were recorded during each harvesting cycle. Essential oil content and essential oil yield were determined by taking 300g of fresh leaves and flowers from composite samples harvested from three middle rows of a plot. Essential oil extraction was done using a hydro-distillation method in a Clevenger apparatus. Experimental data were subjected to analysis of variance (ANOVA) using SAS PROC GLM at  $P < 0.05$ . Differences between means were assessed using the least significant difference (LSD) test.

## **3. RESULT AND DISCUSSION**

### **3.1. Number of Primary Branches Per Plant and Plant Height (cm)**

Pooled mean analysis of variances showed that the main effect of year, intra-row and inter-row spacing, and interaction year with intra and inter-row spacing were significantly ( $p < 0.05$ ) affect the number of branches per plant (Table 1). However, intra-row with inter-row interaction was not significant. Maximum number of primary branches per plant (100.5) and (95.9) were obtained from 70 intra-row and 80inter-row spacing in second year this attribute to the effect of first year harvesting (pruning) that may contribute to the lateral growth of the branch. The lowest number of primary branches per plant (42.6) and (42.3) were recorded from the narrow spacing of 40 cm intra-row and 40cm inter-row spacing in the first year. In the second year harvesting the wider spacing with the some intra-row 58.6% number of primary branch increments was recorded (Table 3). The higher

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number of branches per plant in the wider intra-row and inter-row spacing with plant age might be due to the age of the plant and more availability of growth factors, better penetration of light, consequently, increasing the number of leaves and branch production at wider row spacing.

**Table1.** Pooled means analysis of variance influence of plant population density on yield and yield component of *Lavandula Angustifolia* at Menagesha

Mean square	DF	PH	NBPP	FwPH	DFWPH	DLWPH	AGDB	FOY	LOY
Replication	2	271.4*	211.5ns	0.041ns	0.004ns	0.055ns	0.77ns	11.56	5.62ns
Years	1	5006.7**	37688.8**	0.269*	0.026*	2.115**	14.63**	12.2ns	147.3*
Inter-row	2	1.9ns	187.1*	0.859**	0.086**	4.029**	14.51**	48.6*	330.4**
Intra-row	3	44.2ns	398.6*	0.408**	0.030**	1.978**	11.33**	32.71*	110.4*
Year*intra	3	7.01ns	393.9*	0.061ns	0.005ns	0.052ns	1.650ns	2.90ns	2.149ns
Year*inter	2	101.97*	440.6*	0.111*	0.010*	0.029*	0.984ns	8.08ns	0.67ns
Intra*Inter	6	48.2ns	92.9ns	0.097*	0.011*	0.186*	1.23ns	17.04*	17.48ns
Y*Intra*Inter	6	50.8ns	178.6ns	0.038ns	0.003ns	0.055ns	0.909ns	2.45ns	2.73ns
Error	46	31.0	111.3	0.031	0.003	0.056	0.695	4.30	19.9
CV%		7.21	15.62	29.3	30.1	18.4	31.1	29.4	28.7

DF=Degree of freedom, PH= plant height, NBPP= number of branches per plant, Number of flowers

The reduction in branch number per plants with decreasing intra and inter-row spacing may be due to greater inter-plant competition for incident light, soil nutrition, soil moisture and mutual shading of each other at a high plant density than at low plant density and the age of the plant.

This could be explained in such a way that, as plant spacing increased in both directions and year, ample resources become available for each plant that enhances the lateral vegetative growth of the crop. This finding is in line with the result of Tadesse *et al.* (2016) who reported higher branch number plant<sup>-1</sup> at the wider spacing than the closest in Stevia. Similarly result was also reported by Beemnet *et al.* (2012) on Rose Scented Geranium (*Pelargonium graveolens*), Zewdinesh *et al.* (2011) on Artemisia (*Artemisia annua* L.).

Pooled mean analysis result showed that the main effect of intra-row and inter-row spacing and their interaction were not affected plant height of *Lavandula angustifolia*. However the *Lavandula angustifolia* plant height recorded during the experiment conducted were ranged 75.3cm to 79cm and 75.5cm to 77.1cm height for intra-row and inter-row spacing respectively (Table 2).

**Table2.** Main effects of intra-row and inter-row spacing on yield and yield component of *Lavandula angustifolia* at Menagesha in the pooled mean analysis

Cropping Years	Number of primary branches per plant	Plant height (cm)	Above ground biomass (t/ha)	Flower Oil yield (kg/ha)	Leaf Oil yield (kg/ha)
2016/17	44.69b	85.59a	2.24b	5.49	8.83b
2017/18	90.44a	68.9b	3.14a	4.67	11.69a
LSD 0.05	5.0	2.64	0.39	Ns	2.11
Intra-row (cm)					
40	61.5b	77.87	3.8a	7.0a	13.5a
50	66.15ab	76.78	2.6b	5.0b	10.9ab
60	71.01a	79.0	2.4bc	4.3b	8.7bc
70	71.5a	75.3	1.89c	4.0b	8.0c
LSD	7.1	Ns	0.56	1.4*	2.7
Inter-row (cm)					
40	62.5b	77.1	3.5a	6.7a	14.3a
60	69.2a	76.1	2.7b	4.51b	9.6b
80	71.0a	75.5	1.9c	4.04b	6.9c
LSD 0.05	7.1	Ns	0.51	1.17*	2.35
Intra*Inter	Ns	Ns	ns	*	ns
CV %	17.9	3.9	23.7	29	27

Means followed by the same letter within the same column are statistically no significant at  $P < 0.05$  according to least significant difference (LSD) test;

**Table3.** Interaction effects intra-row, inter-row spacing with years on numbers of primary branch per plants

Cropping years	Number of primary branches per plant								
	Intra-row spacing					Inter-row spacing			
	40cm	50cm	60cm	70cm	Mean	40cm	60cm	80cm	Mean
2016 cropping	42.59d	47.58d	47.0	41.58d	44.69	42.3c	45.6c	46.0c	44.63
2017 cropping	81.47c	84.73bc	95.0ab	100.5a	90.43	82.65b	92.73a	95.9a	90.43
Mean	62.03	66.15	71	71.04		62.48	69.17	70.95	
LSD 0.05	11.53					9.99			
CV%	17.5					17.5			

Means followed by the same letter within the same rows are statistically no significant at  $P < 0.05$  according to least significant difference (LSD) test;

### 3.2. Fresh Flower Yield ( $t\ ha^{-1}$ ) and Dry Flower Yield ( $t\ ha^{-1}$ )

Pooled mean analysis result showed that the main effect of intra-row and inter-row spacing, were very highly significant ( $P < 0.01$ ) and the interaction effect of year with inter-row spacing, the interaction effect of intra-row with inter-row spacing were significantly ( $P < 0.05$ ) affected on fresh flower yield (Table 1). Significantly higher fresh flower yield was obtained in the second year than the first year with the same spacing. Highest fresh flower yield ( $1.21t\ ha^{-1}$ ) was obtained from the combination spacing of 40 x 40cm intra-row and inter-row spacing respectively. Followed by fresh flower yield value obtained from the combined of 40cm inter-row spacing with 50cm intra-row, 60cm intra-row, 70intra-row spacing and 60cm inter-row spacing with 40cm intra-row spacing which were statistically similar with each other, however better than the rest of wider combined of intra-row and inter-row spacing. The lowest fresh flower yield ( $0.343t\ ha^{-1}$ ) was recorded from the combined space of 70cm intra-row and 80cm inter-row, which was statically at par with a fresh flower yield obtained from the combined spacing of 60cmx50cm, 60cm x 70cm, 80cm x 40cm, 80cm x 50cm, 80cm x 60cm intra-row and inter-row spacing respectively (Table 4 & 5).

The interaction effect of intra and inter-row spacing showed significant ( $p < 0.05$ ) difference on dry flower yield  $t\ ha^{-1}$  in the pooled mean analysis. Similar trend were observed with fresh flower yield; Maximum dry flower yield ( $0.367t\ ha^{-1}$ ) was obtained from the combined spacing of 40cm intra-row and 40cm inter-row spacing followed by dry flower yield ( $0.216t\ ha^{-1}$ ) obtained from the combined spacing of 40cm intra-row and 60cm inter-row spacing which were statistically similar with the value recorded from the combined spacing of 40cm inter row with the intra row of 50cm, 60cm, 70cm and 60cm inter-row spacing with 50cm, 60cm intra-row spacing. The lowest dry flower yield ( $109t\ ha^{-1}$ ) recorded from the combined spacing of 60cm intra-row and 80cm inter-row spacing. Increasing the spacing between plants and rows from 40x40cm to 60 x 60cm and 60 x 80cm intra-row and inter-row spacing resulted in 54.2% and 70.3% decreased in dry flower yield ton per hectare of Lavender (Table 4). Increasing fresh flower dry flower yield per hectare was attributed to the accommodation of a number of plants at a closer spacing than in the wider spacing.

**Table4.** Pooled means for interaction effects of intra and inter-row spacing on fresh flower yield, dry flower yield, dry leaf yield ( $t\ ha^{-1}$ ) and flower oil yield ( $kg\ ha^{-1}$ ) of *Lavandula angustifolia* in 2016 and 2017 cropping season

Inter-row (cm)	Intra-row( cm) spacing	Fresh Flower yield ( $t\ ha^{-1}$ )	Dry Flower yield ( $t\ ha^{-1}$ )	Dry leaf yield (t $ha^{-1}$ )	Flower oil yield ( $kg\ ha^{-1}$ )
40cm x	40cm	1.21a	0.37a	2.34a	10.28a
40cm x	50cm	0.66bc	0.21b	1.83b	6.44b
40cm x	60cm	0.69bc	0.19bc	1.57b	6.16bc
40cm x	70cm	0.67bc	0.21b	1.62b	5.19bc
60cm x	40cm	0.74b	0.22b	1.71b	5.74bc
60cm x	50cm	0.51cde	0.16bcd	1.12c	5.69bc
60cm x	60cm	0.57bcd	0.17bcd	1.13c	4.92bcd
60cm x	70cm	0.40de	0.11d	0.83de	3.88cde
80cm x	40cm	0.50cde	0.14cd	1.11c	4.57b-e
80cm x	50cm	0.52b-e	0.16bcd	1.08cd	3.00de

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80cm x	60cm	0.38de	0.11d	0.82de	2.92de
80cm x	70cm	0.34e	0.11d	0.74e	2.25e
LSD		0.22	0.067	0.27	2.36
CV%		29.3	30.1	18.4	29.4

Means followed by the same letter within the same column are statistically no significant at  $P < 0.05$  according to least significant difference (LSD) test

**Table 5.** Interaction effects of years with inter-row spacing on fresh flower oil yield and dry leaf yield per hectare

Cropping years	Flower oil yield(t ha <sup>-1</sup> )				Dry leaf yield (t ha <sup>-1</sup> )			
	Inter-row spacing				Inter-row spacing			
	40cm	60cm	80cm	Mean	40cm	60cm	80cm	Mean
2016	0.669b	0.589bc	0.448cd	0.66	1.59b	0.98c	0.781d	1.12
2017	0.94a	0.521bcd	0.427d	0.54	1.89a	1.41b	1.10c	1.47
Mean	0.80	0.56	0.44		1.74	1.20	0.94	
LSD 0.05	0.176				0.19			
CV%	29.6				18.3			

Means followed by the same letter within the same rows are statistically no significant at  $P < 0.05$  according to least significant difference (LSD) test;

### 3.3. Dry Leaf Yield (t ha<sup>-1</sup>) and Flower Oil Yield (kg ha<sup>-1</sup>)

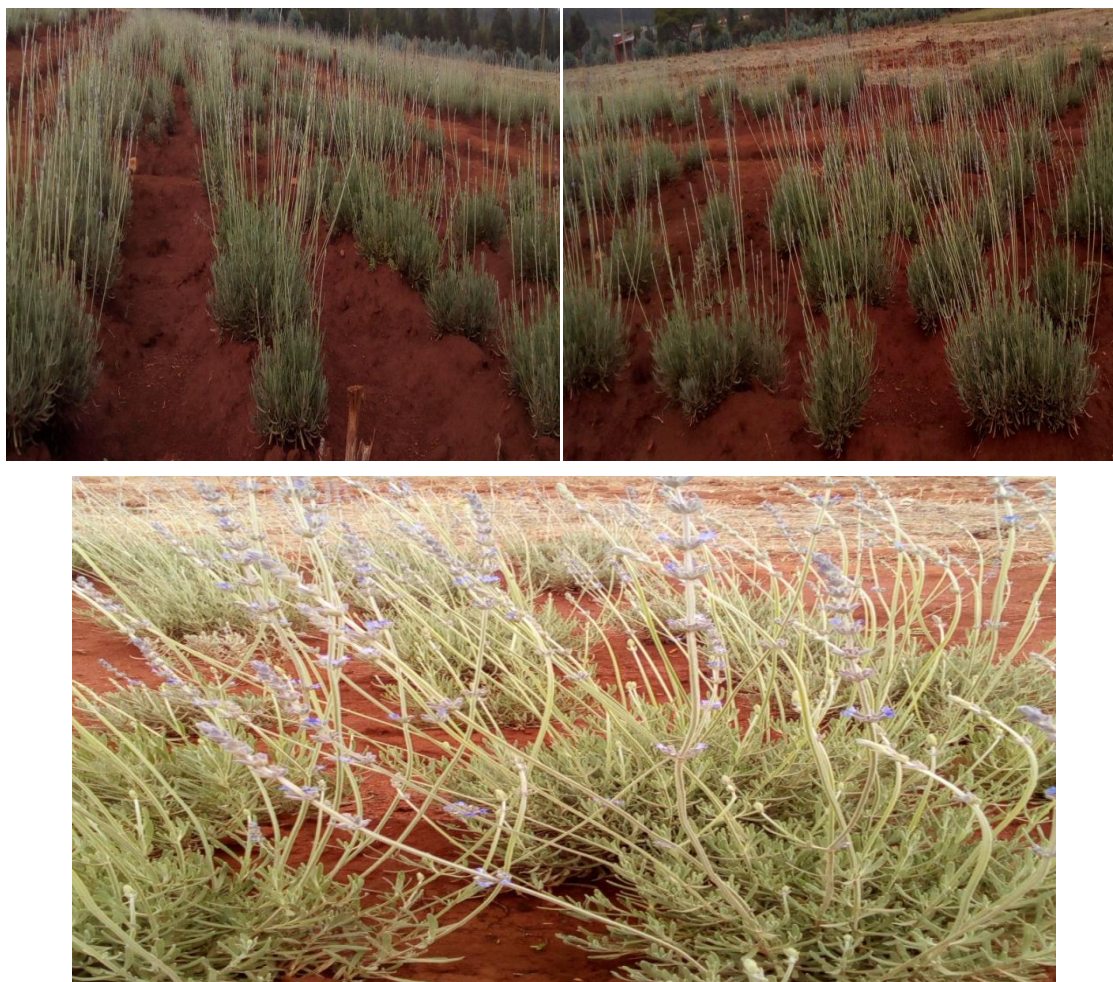
Dry leaf yield and flower oil yield of lavender were significantly ( $P < 0.05$ ) affected by the main effect of year, intra-row, inter-row spacing as well as the interaction of intra-row with inter-row spacing (Table 1).

The significantly higher dry leaf yields and flower oil yield were recorded from the combined spacing of 40cm x 40cm intra-row and inter-row. These were followed by the dry leaf yield and flower oil yield obtained from the combined spacing of 40cm inter-row with 50cm, 60cm, 70cm intra-row and 60cm inter-row with 40cm intra-row spacing. The lowest dry leaf yields and flower oil yield were scored at the combined spacing of 70cm x 80cm intra-row and inter-row respectively. The combination of 40cm, 60cm & 80 inter-rows spacing with the wider (70cm intra-row) spacing over the narrow (40cm intra-row) spacing dry leaf yield was decreased by 30.71%, 64.6% & 68.5%. In agreement with this result, Zigene *et al.* (2012) and Mishra *et al.* (2009) reported that rosemary, fresh leaf yield ha<sup>-1</sup> was lower in wider spacing due to the accommodation of least number of plants in the one-hectare land.

### 3.4. Above Ground Biomass and Oil, Leaf Yield

The pooled mean analysis of variance showed that above ground biomass was significantly influenced by the main effect of intra-row and inter-row spacing. Significantly higher aboveground biomass was recorded in the second year than the first year. This could be due to the age of the plant that can develop more branch, leaf and stem contribute to have high aboveground biomass in second year. Maximum above ground biomass (3.8t ha<sup>-1</sup>) and (3.5 t ha<sup>-1</sup>) were obtained from 40cm intra-row and inter-row spacing respectively. Minimum aboveground biomass (1.89 t ha<sup>-1</sup>) and (1.90t ha<sup>-1</sup>) were recorded from 70 intra-row and 80cm inter-row spacing respectively. As the distance between row and within row, far part aboveground biomass per area was decreased due to the accommodation low number plant per area.

The main effect of intra-row and inter-row spacing were significantly affected oil leaf yield of *Lavandula Angustifoila*. Similarly, significantly higher oil leaf yield also obtained from the second year product than the first year. Maximum oil leaf yield (13.5kg ha<sup>-1</sup>) and (14.3kg ha<sup>-1</sup>) were obtained from 40cm intra and 40cm inter-row spacing. These closely followed by the oil leaf yield obtained from 50cm intra and 60 cm inter-row spacing. Minimum oil leaf yield (8.0kg ha<sup>-1</sup>) and (6.9kg ha<sup>-1</sup>) were recorded from the wider spacing (Table 2). This result agreed with the report of Zigene *et al.* (2012) and Mishra *et al.* (2009) that showed increments of herbage yield and oil leaf yield of rosemary per hectare at closer spacing. The increment of oil yield at a higher density was also due to higher leaf yield/ha at higher density.



**Fig.** Field status during experimental period

#### **4. CONCLUSION**

After going through the results of the present experiment, selections of best inter and intra-row spacing helps to utilize the small land efficiently and intensively. Therefore the two consecutive studies showed that the high economic leaf yield ( $2.34t\ ha^{-1}$ ), flower yield ( $0.37t\ ha^{-1}$ ), flower oil yield ( $10.3kg\ ha^{-1}$ ) and leaf oil yield ( $13.9kg\ ha^{-1}$ ) was recorded from the combined spacing of 40cm intra-row and 40cm inter-row spacing. Thus the best combined intra-row and inter-row spacing for *Lavandula angustifolia* is 40cm x 40cm to attain maximum yield under appropriate management conditions for Menagesha and Similar agro ecology.

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