International Journal of Recycling of Organic Waste in Agriculture (2019) 8:59–66
https://doi.org/10.1007/s40093-018-0228-4

ORIGINAL RESEARCH

A field study on the effect of organic soil conditioners with different placements on dry matter and yield of tomato (*Lycopersicon esculentum* L.)

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Received: 30 March 2018 / Accepted: 27 October 2018 / Published online: 10 November 2018

Abstract

Purpose Four different types of composts were assessed in two methods of application for their potential to support organic tomato yield.

Methods A 2-year experiment was conducted using four different soil conditioners: cow manure (CM), household compost (HC), spent mushroom compost (SMC), and vermicompost (VC). Three different application rates (10, 20, and 30 t ha^{-1} for all composts except VC and 3, 6, and 9 t ha^{-1} for VC) were included as a second factor. Two methods of fertilizer placement (as a row behind the root area and broadcast on the field) were considered as a third factor.

Results The yield was influenced by different soil conditioners and placement method in the first year; in the second year, just interactions were significantly different. Treatments with CM showed significantly higher tomato yield in the first year (103 t ha^{-1}) compared to other composts, but in the second year, SMC produced a higher yield (58 t ha^{-1}). The experiment indicated that the treatment with CM in high level with broadcast application had higher dry matter (DM) production (3.1 t ha^{-1}) in 2014, and treatment with CM in low rate and broadcast application had higher DM production (5.8 t ha^{-1}) in 2015.

Conclusion Compost broadcast on the plots showed a higher yield production in case of similar rates and compost type. The proper rate of compost application is dependent on the method of compost placement.

Keywords Household compost · Organic farming · Soil conditioners · Spent mushroom compost · Vermicompost · Waste management · Compost placement

Introduction

Composts are produced during the process of the decomposition of organic matter by microorganisms in the presence of oxygen. In general, the use of compost maintains and enhances stability and fertility of the agricultural soil (Angin et al. 2017; Zhou et al. 2016). Composts can have direct effects against disease, as well as stimulation of the competing microorganisms and also development of resistance in plants against diseases (Ebrahimi et al. 2018; Carrera et al. 2007). Organic matter is also an important source of energy for bacteria, fungi, and earthworms (Montemurro et al. 2005; Davis and Wilson 2005).

Ensuring the sustainable production of healthy food and eco-friendly products has been of interest to researchers of agricultural sciences and ecology, as well as politicians and practitioners due to high demands by consumers in various countries in the world (Willer and Lernoud 2018). Maintaining soil fertility is one of the main factors affecting the sustainability of food production. Indiscriminate use of chemical fertilizers, coupled with neglected maintenance of the vitality of the soil and the use of destructive methods have caused loss or destruction of the existing population of soil

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organisms (Geisseler and Scow 2014; Ebrahimi et al. 2016). Moreover, the common fertilization system is focused on providing a limited number of macronutrients, while it is scientifically known that plants need at least 13 available minerals in the soil (Atiyeh et al. 2000).

Chemical fertilizers provide short-term nutrient needs of agricultural products, and long-term soil fertility is fallen into oblivion by farmers and agricultural producers. Studies have shown that the excessive and unbalanced use of chemical fertilizers in the long run decreases crop yield, biological activity, soil physical properties, and increases accumulation of nitrates and heavy metals and soil acidity (Ghosh and Bhat 1998; Adediran et al. 2005; Aseri et al. 2008; Yoshida et al. 2016). Optimizing the amount of organic matter in the soil is one of the most basic principles of sustainable agriculture. Soil organic matter is rich in natural resources, such as nitrogen, phosphorus, and potassium (N, P, and K) in organic forms but compared to their mineral forms, availability and mobility of these elements in organic compounds are usually a lot less (Angin et al. 2017). The use of organic debris depends on their quantitative and qualitative characteristics, climate condition, plant type, soil organisms, and management methods. Long-term studies have proven that continued use of chemical fertilizers reduces crop yield due to soil acidification, loss of soil physical and chemical characteristics, and the lack of appropriate micronutrients in these fertilizers (Ghimire et al. 2017; Gliessman and Engles 1998).

In most cases, soils contain sufficient quantities of micronutrients in accordance with the plant needs, but lack of micronutrients occur in some areas, which can reduce the crop yields (Zhou et al. 2016). Shuman et al. (1980) showed that in more than 30 countries, on an average, approximately 30% of the soils are suffering from deficiency of one or more micronutrients. The use of organic fertilizers increases soil organic matter, improves microbial activity, and provides both macro- and micronutrients required for the plant in a more efficient way (Angin et al. 2017).

Compost application is a method to maintain soil fertility. It is well known that organic fertilizers increase soil fertility and provide long-term nutrients by gradual decomposition (Angin et al. 2017; Gaiotti et al. 2017; Zhou et al. 2016). Research that investigated the different compost application methods in organic vegetable fields is quite limited. Thus, closer look at this topic is needed to understand how distribution of compost on the field can influence the final yield and DM. Municipal waste production has amplified due to increasing population growth and urbanization (Lim et al. 2016). One of the most effective methods to neutralize the adverse effects of waste and other plant residues is to separately collect the waste materials, and convert them into compost, to be reused as organic fertilizer and soil conditioner on farmlands (Vogtmann and Fricke 1988; Fricke and Vogtmann 1994; von Fragstein and Schmidt 1999; Olowoake et al. 2018). Studies revealed the effect of municipal compost on increasing the amount of micronutrients in the soil (Zheljazkov and Warman 2004). In regions with arid and semi-arid climates, using municipal solid waste compost as organic fertilizer can be a way to improve the permeability and porosity of the soil due to soil conditions in that areas.

SMC is a byproduct of mushroom production industries in the form of residual compost waste and is a source of humus as well as a useful soil conditioner. Arthur et al. (2012) reported that SMC increased the amount of organic matter and water content in sandy loam soil. Zhang et al. (2012) discovered that SMC could be a good alternative growing medium for tomato and cucumber seedlings in a greenhouse. A study showed that applying SMC up to 10% has a significant effect on height, leaf number, leaf area index, FM and DM of soybean (Jonathan et al. 2013).

VC is a non-thermophilic composting process using various species of worms to create a mixture of peat-like product of decomposed organic residuals (Joshi et al. 2015; Arancon et al. 2004). Vermicomposting promotes a large and active microbial biodiversity population in the soil as compared to composts produced by the thermal process. In addition, VC is a great soil modifier amendment, as it has high porosity, good drainage, and high water-holding capacity (Atiyeh et al. 2000).

Tomato (*Lycopersicon esculentum* L.) is an annual plant and one of the most important crops worldwide. This plant grows in almost all types of soil. Most of the tomato producers use both organic fertilizers and traditional methods, though reports suggest that the quality of the fertilizers can have an adverse effect on the tomato quality (Ghorbani et al. 2008).

In this study, we aim to investigate the impact of four different types of organic fertilizers on tomato yield: (a) vermicompost (VC), (b) household compost (HC), (c) spent mushroom compost (SMC), and (d) cow manure (CM). All composts and CM were used in three different levels (low, medium, and high) based on the local use of these materials by farmers. Furthermore, we applied two different methods of compost placement to study the potentials of soil conditioners in *broadcast* and *row* placement. An effective soil conditioner placement improves nutrient availability for plants and increases their competitiveness against weeds (Nkebiwe et al. 2016).

Materials and methods

The study was established in the Organic Research Station of Ferdowsi University of Mashhad, Iran, located at 36°15′ North latitude and 59°28′ East longitude of Iran for two growing seasons at 2014–2015. The soil type of the experimental field was silt loam with a pH of 7.8 and 1.3 organic matter (Table 1). The site was previously fallow for 5 years before tomato plants were planted for this study in June 2014. The plots were in the similar locations in both the years.

The experiment was conducted using Randomized Complete Block Design (RCBD) with four different types of soil conditioners: (a) VC, (b) HC, (c) SMC, and (d) CM were applied at three different rates: (a) Low, (b) Medium, and (c) High. The amount used for SMC, HC, and CM were 10, 20, and 30 t ha^{-1}, and for VC 3, 6, and 9 t ha^{-1} for low, medium, and high application rates, respectively. The applied quantities of soil amendments were based on the usual application by local farmers (Ghorbani et al. 2008). Besides the quantitative factor, the method of application was also included as third factor: (a) as a *row* behind the root area and (b) *broadcast* on the field (Nkebiwe et al. 2016). Soil conditioners were tested and analyzed for chemical and nutritional values in both the years (Table 2).

Each plot contained four rows, spaced 150 cm apart and 4 m in length. Each tomato plant was placed 50 cm apart within each row and each plot had two furrows for irrigation. All the samples were taken from the two middle rows of each plot. Tomato seeds of *Early Urbana Y* variety provided by *Yekan Bazr* Co. were used. Eight-week-old transplants were transplanted to the field by hand on the first week of June 2014 in the first year, and on the third week of May 2015 in the second year based on the weather condition.

During the growing season, plots were observed to protect against any disease and pests, where no significant disease or pest invasion was observed. Each year tomatoes were harvested three times during the growing season at 13, 16, and 19 weeks after transplanting, beginning in the first week of September in the first year, and the second week of September in the second year. In each harvest, the whole plot area was harvested, but all other samplings for further analysis were obtained from the two middle rows of each plot. Hand-weeding was done during the growing season to control the weed population. Plot yields were converted to (t ha^{-1}) for the statistical analysis and presentation of results. After the last harvest, five plants were taken from the two middle rows of each plot for DM and nutrient uptake analysis.

Data were analyzed by analysis of variance (ANOVA) and the mean values were compared with Tukey and LSD test with the help of MINITAB software. The probability level for determination of significance was either $p=0.05$ or $p=0.01$.

Table 1 Soil properties of the experimental field in the depth of (0–30 cm)

Year	2014	2015
Texture	Silt loam	Silt loam
pH	7.8	7.9
EC (dS m^{-1})	2.4	2.4
Organic *C* (%)	3.0	1.1
Total *N* (%)	0.16	0.16
C/*N*	18.1	7.1
Available P (mg kg^{-1})	298	193
Available K (mg kg^{-1})	748	237
NO_3 (mg kg^{-1})	7.0	3.0
Fe (mg kg^{-1})	7.9	2.6
Zn (mg kg^{-1})	2.1	1.3
Cu (mg kg^{-1})	1.4	2.4
Mn(mg kg^{-1})	14.1	7.9

Table 2 Chemical characteristics of applied organic fertilizers

Year	Type of fertilizer	N	P	K	Zn	Cu	Fe	Mn	EC	pH
		(g kg^{-1})			(mg kg^{-1})				(dS m^{-1})	
2014	CM	14	3	11	92	28	8778	350	4.5	8.2
	HC	20	4	8	836	165	3771	316	5.6	8.0
	SMC	21	3	7	226	24	2671	301	6.1	7.9
	VC	21	5	6	568	171	5255	210	2.9	7.9
2015	CM	11	4	10	89	21	8771	331	5.0	8.0
	HC	19	5	9	834	171	3812	301	5.4	7.8
	SMC	20	4	8	227	25	2660	303	5.1	8.1
	VC	19	6	6	563	168	5230	207	3.1	8.0

CM Cow Manure, *HC* Household Compost, *SMC* Spent Mushroom Compost, *VC* Vermicompost

Results and discussion

Analysis of variance shows that the cumulative yield responded to all factors in the first year. Table 3 indicates that interaction between compost type and compost rate was also significant ($p \leq 0.01$). In this experiment, tomato responded to the interaction of all factors at both the experimental years. Compost is a good resource to release nutrients during growing season (Abbasi et al. 2002), and to ensure a sustainable and healthy production of tomato. Erhart et al. (2005) reported an increase of yield up to 10% for compost treatments as compared to the control in wheat, barley, and potato for 10 years. They also reported that yield response to compost amendment was increased over time. Furthermore, Mehdizadeh et al. (2013) have also illustrated that tomato fruit yield has been increased by 94% in comparison with control.

In 2014, treatments with CM produced significantly ($p \leq 0.01$) more tomatoes (103 t ha^{-1}) than the other fertilizers; however, in the second year, the differences were not significant (Table 4). Higher yield production in treatments with CM could be due to higher mineralization of organic matter in CM, which can provide enough nutritional release for the plant (Angin et al. 2017). Table 4 shows that higher compost rates did not produce a higher amount of tomatoes in the first year. Yield productions in treatments with a medium compost rate were significantly higher (98 t ha^{-1}) than treatments with high compost rate (88 t ha^{-1}). Reduction of yield at a higher level of soil conditioner application might be linked to salinity of the soil by compost and organic fertilizer application, while treatments with VC and lower EC showed less reduction compared to other composts (Tables 2, 5). This reduction is higher at SMC with row application and HC with broad application, which can be due to the incorporation of salt into the soil. Similar results were reported by Angin et al. (2017). However, applying nutrients have different effects on soil microbes and plant communities. Studies show that N fertilizers can suppress soil microorganisms (Geisseler and Scow 2014). In the second year, there was no significant difference between treatments with different compost rates.

In the first year of the experiment, treatments with SMC at a medium rate with broadcast application produced the maximum amount of tomato (120 t ha^{-1}), which was not significantly different with treatments of the same compost in low rate and with row placement (Table 6). This could be explained by the availability of compost for root area in row application. Besides, SMC in higher rates produced less tomato in row application, which might be due to high salinity around the root area (Table 2). All soil conditioners showed a high amount of tomato production with the medium rate and broad application with the exception of VC (Table 5). This result is understandable because VC has been applied 14 t ha^{-1} less than the other composts due to its local consumption by farmers. Table 5 demonstrates that using CM does not necessarily produce higher yield. A study by Mehdizadeh et al. (2013) published a similar result with regard to the application of HC and CM in tomato production. In their experiment, with the application of 20 t ha^{-1} for HC and CM, 33 and 27 t ha^{-1} of tomato were produced, respectively.

In the second year of experimentation, the yield was significantly lower, which could be due to transplant or weather conditions in transplanting period. Besides, C:N ratio has decreased in the second year (Table 1) though organic matter decomposition will increase, which might cause a reduction in the supply of soil organic matter (Reicosky et al. 1995).The differences between treatments (Table 5) during the second year were not as large as compared to the first year. This could be a result of the homogeneity of the soil

Table 3 Mean square of tomato yield for different factors in the growing seasons of 2014–15

Year		2014	2015
Source	DF	MS	MS
Replication	2	454.7^{NS}	175.7^{NS}
Organic fertilizer (A)	3	715.7^{**}	137.1^{NS}
Rate (B)	2	564.6^{*}	189.0^{NS}
Application (C)	1	1376.7^{**}	190.5^{NS}
(A×B)	6	753.97^{**}	99.9^{NS}
(A×C)	3	69.5^{NS}	112.3^{NS}
(A×B×C)	6	1040.4^{**}	444.3^{*}
Error	46	–	–

Means with *, ** and NS are significant with $p \leq 0.05$, $p \leq 0.01$ and not significant, respectively

Table 4 Effects of different soil amendments on yield (t ha^{-1}) for both years

Year	Type of fertilizer				Rate of application		
	CM	HC	SMC	VC	Low	Medium	High
2014	103 a	94 b	90 b	89 b	95 uv	98 u	88 v
2015	56 A	55 A	58 A	52 A	57 U	52 U	57 U

Means followed by different letters are significantly different ($p \leq 0.05$, LSD test)

CM Cow Manure, *HC* Household Compost, *SMC* Spent Mushroom Compost, *VC* Vermicompost

Table 5 Effects of different soil amendments with different rate and application method on yield (t ha^{-1})

Year	Application	Rate	Type of fertilizer			
			CM	HC	SMC	VC
2014	Row	Low	99 b-e	77 f-i	112 abc	85 e-h
		Medium	93 c-g	107 a-d	78 ghi	72 hie
		High	109 abc	87 d-h	61 i	92 c-h
	Broadcast	Low	99 b-f	100 a-e	76 ghi	112 abc
		Medium	115 ab	114 ab	120 a	85 e-h
		High	103 a-e	75 ghi	92 c-g	88 d-h
2015	Row	Low	67 uv	53 uvw	64 uv	47 vw
		Medium	48 vw	53 uvw	55 uv	53 uvw
		High	69 u	62 uv	53 uvw	62 uvw
	Broadcast	Low	46 vw	60 uv	53 uvw	64 uv
		Medium	59 uv	56 uv	64 uv	32 w
		High	49 uvw	47 vw	62 uv	53 uv

Means followed by different letters are significantly different ($p \leq 0.05$, LSD test)

CM Cow Manure, *HC* Household Compost, *SMC* Spent Mushroom Compost, *VC* Vermicompost

Table 6 Mean square for shoot DM for both years

Year		2014	2015
Source	DF	MS	MS
Replication	2	0.27^{NS}	0.63^{NS}
Organic fertilizer (A)	3	2.01^{**}	1.99^{*}
Rate (B)	2	0.04^{NS}	0.76^{NS}
Application (C)	1	1.51^{*}	0.60^{NS}
(A×B)	6	0.60^{NS}	1.30^{*}
(A×C)	3	0.52^{NS}	1.91^{*}
(A×B×C)	6	1.00^{**}	1.75^{**}
Error	46	–	–

Means with *, **and NS are significant with $p \leq 0.05$, $p \leq 0.01$ and not significant, respectively

or enhancement of soil quality after 1 year of plantation with organic soil conditioners (Table 1). In the second year, CM treatment with high rate and row placement produced a higher amount of yield (69 t ha^{-1}), which did not differ significantly with any other composts using the same rate and placement method. On the contrary, tomato yield decreased in treatments with CM more than the other soil conditioners. However, the differences between these diminished treatments in the second year are not significant. This indicates that composts have a better effect over time in comparison with CM. Studies showed that we cannot expect a big response on plant growth in a short time because compost is not a rich source for N availability, but there is evidence that compost is a suitable amendment for long-term improvement of soil organic matter (Abbasi et al. 2002; von Fragstein and Schmidt 1999). Mehdizadeh et al. (2013) showed that HC had a significantly better effect as compared to CM, poultry manure, and sheep manure, in cumulative tomato yield and the number of tomato per plant. In the proposed study, there was a reduction on tomato yield in the second year due to warm weather during the transplanting phase. Flowering is an important phase in plant development as the plants are vulnerable to environmental stress. It is the stage of plant development that determines when vegetables are ripe for harvest (Wien 1997). This amount did not show any significant difference with other soil conditioners in different application rates. The analysis of variance between 2 years of experiment was not significantly different ($p \leq 0.05$) for yield production (Table 3).

Vermicomposting had less effect on the production compared to other fertilizers in this experiment; however, the amount of VC applied was almost one-third of the amount of other fertilizers, based on the local consumption by farmers. For this reason, VC can be considered as a suitable fertilizer and soil conditioner for tomato production when applied at a relatively higher rate (9 t ha^{-1}), as it could have significantly increased tomato production during the second year. Yang et al. (2015) reported that tomato yield with VC amendment had greater yield in comparison with horse and chicken composts, and also chemical fertilizer under medium irrigation systems. Compared with the traditional composting process, VC has a higher degree of humification (Jeyabal and Kuppuswamy 2001). Special substances in VC, such as plant growth regulators that are biologically active, and also, the existence of functional microorganisms due to higher soil microbial biomass are the reasons that separate VC from other composts (Arancon et al. 2003; Amossé et al. 2013; Yang et al. 2015). Studies indicate that VC had a positive effect on sugar content and vitamin C level in tomato fruits compared with other fertilizers (Yang et al. 2015).

Analysis of variances for plant DM illustrates that different organic fertilizers as well as the methods of application differed markedly between treatments in the first year of production. Whereas in the second year, only different fertilizer type showed significant difference, but compost rate and placement method have no significance. In both the years, the interaction effect between factors shows significant differences between treatments (Table 6).

In the first year, treatments with CM produced more DM (2.4 t ha^{-1}) than treatments with HC and SMC while their differences with VC treatments (2.1 t ha^{-1}) were not significant. However, in the second year, treatments with VC produced markedly lower DM (2.8 t ha^{-1}) than treatments with CM (3.6 t ha^{-1}). Despite that the yield production decreased in the second year, the DM concentration had increased in the same year (Table 7). Studies show that DM content has a direct correlation with the improvement of the nutritional status of soil and the soil structure (Azarmi et al. 2008; Gutiérrez-Miceli et al. 2007).

Table 8 indicates that treatment with CM in high rate and with broad application created the largest DM (3.1 t ha^{-1}) in 2014. This amount did not differ compared with other treatments with CM, different rates, and different application methods. This finding is relevant to that of Pellejero et al. (2017) on lettuce, in which treatments with higher compost dosage showed higher root dry weight as well. This also included treatments with other fertilizers with high rate and broadcast application. Based on these results, treatments with SMC in high rate and row placement, as well as HC in low rate and row placement, showed the lowest DM content (1.2 t ha^{-1} and 1.2 t ha^{-1}, respectively) in 2014. On the contrary, treatment with CM in low rate and broadcast application had the highest DM (5.8 t ha^{-1}) in the second year, and this amount did not differ significantly with treatments of CM and SMC in medium rate and HC in high rate, all with broadcast application and treatment of SMC in high rate and row placement (3.6, 3.6, 3.9, and 3.5 t ha^{-1}, respectively). As the result indicates in Tables 6 and 8, DM content was significantly higher in the second year of experiment owing to the availability of compost around the plot area. The analysis of variance between 2 years of experiment was not significantly different ($p \leq 0.05$) for DM production (Table 6).

Table 7 Effects of different soil amendments on shoot DM (t ha^{-1}) for both years

Year	Type of fertilizer			
	CM	HC	SMC	VC
2014	2.4 a	1.7 b	1.8 b	2.1 ab
2015	3.6 u	3.1 uv	3.2 uv	2.8 vb

Means followed by different letters are significantly different ($p \leq 0.05$, Tukey test)

CM Cow Manure, *HC* Household Compost, *SMC* Spent Mushroom Compost, *VC* Vermicompost

Conclusion

The results of the proposed study indicated that different types of fertilizers, different rates, and also different placements could impact the final result in organic tomato production. The experiment showed that VC is a good alternative to reduce the consumption of fertilizers, while treatments with VC could produce a large amount of tomatoes (89 and 52 t ha^{-1} in 2014–2015, respectively) with way less amount of compost application. The proper compost rate is dependent on the compost placement method. The field study showed that compost application as broadcast resulted in 65% higher yield than as a row in medium and high rate

Table 8 Effects of different soil amendments with different rates and application methods on DM (t ha^{-1})

Year	Application	Rate	Type of fertilizer			
			CM	HC	SMC	VC
2014	Row	Low	2.2 abc	2.0 cc	1.7 abc	1.9 abc
		Medium	2.6 abc	1.5 abc	1.44 bc	2.2 abc
		High	1.9 abc	1.9 abc	1.2 c	2.5 abc
	Broadcast	Low	2.9 abc	1.7 abc	1.9 abc	3.1 ab
		Medium	2.5 abc	1.7 abc	2.3 abc	1.4 bc
		High	3.1 a	2.3 abc	1.9 abc	1.5 abc
2015	Row	Low	3.0 v	3.3 v	3.1 v	3.0 v
		Medium	2.9 v	3.3 v	3.8 v	2.4 v
		High	3.3 v	3.3 v	3.5 uv	2.8 v
	Broadcast	Low	5.8 u	2.7 v	2.7 v	2.8 v
		Medium	3.6 uv	2.2 v	3.6 uv	2.6 v
		High	3.0 v	3.9 uv	3.0 v	3.1 v

Means followed by different letters are significantly different ($p \leq 0.05$, Tukey test)

CM Cow Manure, *HC* Household Compost, *SMC* Spent Mushroom Compost, *VC* Vermicompost

of application and up to 68% less production in broadcast compared to row placement in low application for SMC in the first year. Furthermore, broadcast application of HC and VC is more effective compared to row placement. However, there was no significant difference between different placements in the second year. To conclude, the study demonstrated that composts such as HC and SMC can be a good solution to manage the industrial and municipal wastes and using their potential for agricultural production and also soil improvement. Further studies should be conducted on different placement methods to optimize the compost rate consumption as much as possible. In both years treatments with a vermicompost well less yield promoting compared to the other composts, but the use efficiency most have been more with regard to lower levels of application.

Acknowledgements The input of all colleagues in the research farm of Ferdowsi University of Mashhad is appreciated. We thank Mr. A. Sadeghi, Mr. M. Soheili and H. Nikoo for their technical support during the experimental period. We also appreciate all the efforts Prof. R. Ghorbani put through to make this experiment happen.

Compliance with ethical standards

Conflict of interest The authors declare that they have no potential conflicts of interests. Also this article does not contain any studies with human participants or animal performed by any of the authors.

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