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RESEARCH ARTICLE

Integrated Plant Nutrients Supply and Foliar Nutrition on Yield and Quality of Okra [*Abelmoschus esculentus* (L.) Moench] Hybrid COBhH-4 in Alfisols

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Abstract

The present investigation was undertaken at Agricultural College and Research Institute, Killikulam during rabi season of 2017-18 in Alfisols with a main objective of evaluating the effect of IPNS and foliar nutrition on yield and quality of okra fruits COBhH –4 . The thirteen treatments comprised of absolute control, STCR-IPNS alone, 100 per cent N through FYM alone and in combination with foliar spray of micronutrients, moringa leaf extract, aloe vera leaf extract and amino acids. The treatment received STCR - IPNS + amino acids (50 ppm)+ micronutrients (Fe, 1.0%, Zn, 0.5% & B, 0.3%) + aloe vera leaf extract (50 ppm) + moringa leaf extract (50 ppm) (Foliar Spray) recorded higher values of yield parameters *viz.,* no. of fruits per plant (25.0), no. of pickings (18.7), fruit length (18.7 cm), fruit girth (2.50 cm) and fruit yield (24.24 t ha^{-1}). The same treatment recorded higher crude protein content (18.19%) and ascorbic acid (13.66 mg/100g) whereas higher TSS (2.73%) and mucilage (1.74%) content of okra fruits were recorded by the treatment receiving FYM + foliar spray of amino acids, micronutrients, moringa and aloe vera leaf extracts compared to control. Both the treatments STCR-IPNS and 100 per cent N through FYM in combination with foliar spray of micronutrients, moringa leaf extract, aloe vera leaf extract and amino acids recorded lower values of days to 50 % per cent flowering (38.6 and 38.7) and days to fruit maturity (39.60 and 39.30) respectively. The per cent fruit yield increase over control was 136 and 125 per cent respectively, for STCR-IPNS and FYM both in combination with amino acids + micro nuttrients + aloe vera + moringa leaf extract as foliar spray. The effect of micronutrients as foliar along with STCR-IPNS was the next best treatment. The highest BCR of 5.27 was recorded by STCR-IPNS with foliar spray of micronutrients, moringa leaf extract, aloe vera leaf extract and amino acids followed by 4.92 by STCR IPNS with foliar spray of moringa leaf extract (T_{10}).

Keywords: *STCR – IPNS, FYM, Foliar nutrition, Okra, Performance, Alfisol*

Introduction

Okra (*Abelmoschus esculentus*) commonly known as bhendi, is a herbaceous annual plant belonging to the family Malvaceae and an economically important vegetable crop grown in many parts of tropics and sub-tropics. In India, okra is cultivated in an area of 5,01,000 ha with 57,83,000 MT production and in Tamil Nadu, the area and production are 11,000 ha and 75,400 MT respectively (NHB, 2016-2018). Growers use heavy dose of inorganic sources of plant nutrients due to the increasing demand for the produce and to realize higher fruit yield. This causes imbalanced fertilization of nutrients that results in low yield and poor quality of okra fruits. The exclusive application of inorganic fertilizers without proper substitution of organic manures may create a deleterious effect on soil fertility due to limitation of one or more nutrients including micronutrients and poor soil health leading to decline in productivity (Satyanarayana *et al.*, 2002). Therefore, the alternative choice of the farmers for maintaining the sustainable production can be achieved by the application of nutrients through organic amendments such as farm yard manure and bio fertilizers.

The basic concept underlying the principle of Integrated Plant Nutrient System (IPNS) is the maintenance and possible improvement of soil fertility for sustaining the crop productivity through the combined use of organic

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manure, chemical fertilizer and bio-fertilizer. Organic manures not only balances the nutrient supply but also improves the physical, chemical and biological properties of soil. Thus, a strategy for judicious combination of both organic and inorganic sources of nutrient is the most viable option for nutrient management (Salvi et al., 2015). Foliar fertilization with multinutrients to achieve balanced plant nutrition is considered to play a significant role in modern sustainable vegetable production (Saravaiya et al., 2014).

Micronutrients required for optimal growth play vital role in plant physiology and biochemical process (Alia *et al.*, 2015). Plant hormones can be used to increase yield per unit area because they influence every phase of plant growth and development. The aloe vera leaf peeling extract and powder contain the essential nutrients and phytohormones necessary for plant growth enhancement (Hamman, 2008). The minerals such as calcium, magnesium, potassium, phosphorus, iron, manganese, zinc and copper along with antioxidants are rich in moringa leaf extract (Moyo *et al.,* 2011) and the yields of onions, bell pepper, soya beans, sorghum, coffee, tea, chili, melon and maize crops were increased when sprayed with moringa leaf extract (Fuglie, 2000). Amino acids are well known biostimulants with positive effects on plant growth and okra yield (Katharine *et al.*, 2016). Keeping this in view, the present investigation was undertaken to find out the best combination of organic and inorganic fertilizers along with plant extracts as foliar spray at lower concentration for obtaining the maximum fruit yield of okra crop.

Material and Methods

The field experiment was conducted at 'D' block (Field No. D-27) of Agricultural College and Research Institute, Tamil Nadu Agricultural University, Killikulam during October, 2017 - January, 2018 to study the effect of IPNS and foliar nutrition including micronutrients and plant extracts on yield and quality of okra. The experiment was laid out in RBD design with three replications. The texture of the experimental soil was sandy clay loam, neutral in reaction and was low, medium and high in available N, P and K respectively. The soil was classified as fine, loamy, isohyperthermic family of Typic Haplustalf. The soil was deficient in DTPA- Zn, Fe, B and Cu, whereas sufficient in DTPA – Mn content in soil. The treatment details include:

T_1 - Control; T_2 - STCR-IPNS; T_3 - 100% N through FYM; T_4 -T_2 + Amino Acids (AA) -Foliar spray (FS); T_5 - T_3 + Amino Acids (FS); T_6 - T_2 + Micronutrients (MN) (FS); T_7- T_3 + Micronutrients (FS); T_8 - T_2 + Aloe vera Leaf Extract (ALE) (FS); T_9 - T_3 + ALE (FS); T_{10} - T_2 + Moringa Leaf Extract (MLE) (FS); T_{11} - T_3 + MLE (FS); T_{12} - T_2 + AA + MN + ALE+ MLE (FS); T_{13} - T_3 + AA + MN + ALE+ MLE (FS). All the treatments were given the same dose of NPK fertilizer, but FYM was applied @ 20 t ha^{-1} in treatments T_3, T_5, T_7, T_9, T_{11} and T_{13}. Micronutrients namely Zn, Fe and B @ 0.5, 1.0, 0.3 per cent respectively and plant extracts and amino acids @ 50 ppm as foliar spray were given on 25, 45 and 60 days after sowing for the respective treatments. As the effect of plant extracts was unknown on fruit yield of okra, a lower concentration of 50 ppm (0.05%) was fixed as foliar spray.

Seeds were sown at 45×30 cm spacing on October 11, 2017. Manures and fertilizers were applied to the crop as per the recommended dose. The organic manures were applied one week before sowing and full dose of phosphorus and potassium and half dose of nitrogen as per treatment were applied just before the sowing. The remaining half dose of nitrogen applied 30 days after sowing. Five plants were randomly tagged in each plot to record the yield. The fruit protein content was determined by nitrogen percentage in fruit by kjeldahl's method and was multiplied by 6.25 as multiplication factor. The quality parameters were analysed by following the standard procedures (crude protein : Humphries, 1956; mucilage : Whistler and Conrad, 1954; ascorbic acid : Roe and Kuether, 1943; total soluble solids : Ranganna,1986). The data were subjected to statistical scrutiny (Gomez and Gomez, 1984).

Results and Discussion

Yield attributes

The yield parameters namely the number of fruits per plant, fruit length and diameter were significantly influenced by different treatments (Table 1). The highest number of fruits per plant (24.8), fruit length (18.7cm) and diameter (2.50 cm) were recorded with the treatment receiving STCR-IPNS + AA + MN + ALE+ MLE (FS) (T_{12}) followed by FYM in a similar combination (T_{13}). The lowest number of fruits, fruit length and diameter were recorded in absolute control T_1. The treatments T_{12} and T_{13} recorded lower values of days to 50 per cent flowering (33.6 and 38.7) and days to fruit maturity (39.3 and 39.6) followed by all treatments except T_3, T_2 and T_1. Lesser number of days to opening of flower after transplanting (30.0) in tomato plant was registered by the application of 15 t ha^{-1} FYM (Manohar *et al.*, 2013). Similar results were reported by Pandav *et al.* (2016), with regard to days to fruit maturity in brinjal by the application of micronutrients. This might be due to increased production of more number of productive flowers, percentage of fruit set and more allocation of photosynthates towards the economic part. The higher number of fruits due to foliar spray of micronutrients

Table 1. IPNS and foliar nutrition on yield components of okra (COBhH-4)

Treatments	Days to 50% flowering	Days to fruit maturity	Number of fruits per plant	Number of pickings	Fruit length (cm)	Fruit diameter (cm)	Fruit yield (t ha^{-1})	Per cent increase over control
T_1 - Control	44.00	43.0	15.3	12.8	13.4	1.22	10.28	-
T_2 - STCR-IPNS	43.25	42.0	19.8	14.6	14.6	1.46	19.85	93.09
T_3 - 100% N through FYM	43.03	41.0	19.6	14.2	14.2	1.44	19.20	86.77
T_4 - T_2 + Amino Acids (AA) - Foliar spray (FS)	42.58	40.8	20.4	15.5	15.1	1.70	20.18	96.30
T_5 - T_3 + Amino Acids (FS)	42.95	41.3	20.1	14.8	14.9	1.63	19.94	93.97
T_6 - T_2 + Micronutrients (MN) (FS)	39.46	39.8	22.6	17.3	17.4	2.25	20.80	102.33
T_7 - T_3 + Micronutrients (FS)	39.85	40.0	21.2	16.8	16.9	2.20	20.45	98.93
T_8 - T_2 + Aloe vera Leaf Extract (ALE) (FS)	41.26	41.7	21.0	16.5	14.6	1.90	20.26	97.08
T_9 - T_3 + ALE (FS)	41.34	40.9	20.7	16.1	14.0	1.80	20.15	96.01
T_{10} - T_2 + Moringa Leaf Extract (MLE) (FS)	40.28	40.9	21.4	16.9	15.9	2.06	21.80	112.06
T_{11} - T_3 + MLE (FS)	40.62	40.6	21.2	16.6	15.4	2.03	21.06	104.86
T_{12} - T_2 + AA +MN + ALE+ MLE (FS)	38.62	39.6	24.8	18.7	18.7	2.50	24.24	135.80
T_{13} - T_3 + AA +MN + ALE+ MLE (FS)	38.74	39.3	24.2	18.3	18.2	2.40	23.10	124.71
SEd	1.20	0.91	0.89	0.53	0.32	0.10	0.52	-
CD (p = 0.05)	2.48	1.8	1.86	1.10	0.68	0.22	1.09	-

might be due to the enhanced photosynthetic activity, resulting in increased production and accumulation of carbohydrates and favorable effect on vegetative growth and retention of flowers and fruits, which might have increased the number and weight of fruits. An increased number of fruits in response to micronutrients (B and Zn mixture) has been reported by Basavarajeswari *et al*. (2008). The application of RDF + (B, Zn, Cu and Mn) @ 100 ppm each recorded the highest number of fruits per plant in tomato (Saravaiya *et al.,* 2014). Foliar application might have enhanced the availability of nutrients and plant growth hormones which improved the translocation of nutrient from root to plant parts which resulted in increased yield parameters. Similar findings were reported by Singh (2015). The significant effect of amino acid formulation @ 4.0 L ha^{-1} foliar spray in okra was reported by Katharine *et al.* (2016). Manohar *et al*. (2013) reported that the treatment application of FYM 15 t ha^{-1} recorded the highest number of pickings (8.42) in okra. Fruit diameter of okra varied from 1.22 to 2.50 cm. Ullah *et al.* (2008) reported that the combined application of NPK as 60 per cent organic + 40 per cent inorganic recorded the highest brinjal fruit length and diameter. The increase in yield parameters might be due to the improved vegetative growth and early flowering.

Yield

The data recorded on okra fruit yield (t ha^{-1}) as influenced by different treatments are furnished in Table 1 and the effect was found to be significant. The okra fruit yield ranged from 17.28 to 24.24 t ha^{-1}. The treatment (T_{12}) which received STCR- IPNS + AA + MN + ALE+ MLE (FS) recorded significantly the highest okra fruit yield (24.24 t ha^{-1}) followed by the treatment T_{13} (23.1 t ha^{-1}), T_{10} (21.8 t ha^{-1}), T_{11} (21.0 t ha^{-1}), T_6 (20.8 t ha^{-1}) and T_7 (20.5 t ha^{-1}), the latter four being comparable with each other wherein STCR-IPNS/ 100% FYM was applied with moringa leaf extract / micronutrients as three times spray. Whereas, the lowest fruit yield (10.3 t ha^{-1}) was recorded by control.

The per cent yield increase over control ranged from 93 to 136 per cent. The highest per cent yield increase was recorded by T_{12} (136) followed by T_{13} (125), T_{10} (112), T_{11} (105), T_6 (102) and T_7 (99) over T_1 (control). Whereas the STCR-IPNS and 100 per cent N through FYM in alone registered an increase of 93 and 87 per cent yield increase over control.

It was observed that micronutrients applied alone or combination with moringa leaf extract /aloe vera extract/ amino acids was found to be significantly effective in increasing the yield of okra as compared with control. Micronutrients involves in different physiological processes like enzyme activation, electron transport, chlorophyll formation and stomatal regulation etc. which ultimately resulted in enhanced photosynthesis

activity and accumulation of carbohydrates thereby having favorable effect on vegetative growth and retention of flowers and fruits and increased yield of okra (Mehraj *et al.*, 2015). Boron plays an essential role in the development and growth of new cells in the plant meristem, improves the fruit quality and fruit set. It is needed by the crop plants for cell division, nucleic acid synthesis, uptake of calcium and transport of carbohydrates (Singh *et al*., 2017).

Table 2. IPNS and foliar nutrition on quality parameters of okra fruits (COBhH-4)

Treatments	Crude protein (%)	Ascorbic acid ($mg.100g^{-1}$)	Total soluble solids (%)	Mucilage (%)
T_1 - Control	12.54	9.00	1.30	1.12
T_2 - STCR-IPNS	14.11	10.05	1.59	1.24
T_3 - 100% N through FYM	14.82	9.84	1.57	1.32
T_4 - T_2 + Amino Acids (AA) - Foliar spray (FS)	17.44	10.31	1.67	1.37
T_5 - T_3 + Amino Acids (FS)	16.59	10.27	1.65	1.40
T_6 - T_2 + Micronutrients (MN) (FS)	15.14	12.88	2.64	1.50
T_7 - T_3 + Micronutrients (FS)	15.63	12.86	2.56	1.58
T_8 - T_2 + Alo evera Leaf Extract (ALE) (FS)	14.45	11.47	1.98	1.42
T_9 - T_3 + ALE (FS)	14.97	10.85	1.92	1.45
T_{10} - T_2 + Moringa Leaf Extract (MLE) (FS)	15.44	12.64	2.25	1.48
T_{11} - T_3 + MLE (FS)	15.21	12.28	2.18	1.50
T_{12} - T_2 + AA +MN + ALE+ MLE (FS)	18.19	13.66	2.67	1.66
T_{13} - T_3 + AA +MN + ALE+ MLE (FS)	17.75	13.18	2.73	1.74
SEd	0.09	0.19	0.09	0.03
CD (p = 0.05)	0.19	0.30	0.19	0.07

Application of organics with inorganic sources and foliar application might have had an impact on increased content and uptake of nutrients, enhanced fruit length, fruit girth and ultimately increased the average fruit weight of *A.esculentus.* Also the increase in fruit yield might be due to balanced supply of nutrients over the crop period from organics resulted in enhanced the root development, better translocation of nutrients, better uptake and yield which is in agreement with findings of Akanbi *et al.* (2010) and Salvi *et al.* (2015).

The aloe vera leaf extract contain the essential nutrients and phytohormones necessary for plant growth enhancement and can be exploited effectively not only as a biostimulant [as it is found to contain IAA - Indole Acetic Acid and GA_3 -Gibberellic Acid] but also as a herbal manure (as it found to contain amino acids, polysaccharides and enzymes) for stimulating the growth and yield parameters of crops (Kalpana, 2008) might be the reason for increased yield over control.

The effect of moringa leaf extract was found to be significant compared to aloe vera leaf extract and amino acids.The moringa leaf extract is considered as a natural plant growth regulator where, it is a source of zeatin which is natural derivative of cytokinin (Fuglie, 2000), proteins, vitamin E, phenolics, ascorbates, essential amino acid and several mineral elements as a potential natural growth stimulant which played an important role in cell division and cell elongation, might have been involved in promoting more photosynthesis thereby might have enhanced the plant yield (Matthew, 2016).

Quality attributes

Crude protein

Data presented in Table 2 showed that the protein content of okra fruits ranged from 12.54 to 18.19 per cent. The highest protein content of okra fruit (18.19) was recorded in the treatment receiving STCR- IPNS + AA + MN + ALE+ MLE (FS) (T_{12}) followed by $T_{13,}$ T_4 and T_5 (17.75, 17.44 and 16.59 % respectively). Application of organic and inorganic source of nitrogen might have increased the protein content of fruit (Wagh *et al*., 2014). The nutrient contained in STCR-IPNS/ FYM in combination with amino acids/ plant extracts would have helped in enhancing the protein synthesis and helped in its efficient storage in okra fruits. Similar results were reported in okra (20.6 %) (Katharine *et al.*, 2016) and in alfalfa (22.0 %) (Pooryousef and Alizadeh 2014) by the application of amino acids and in okra by boron (Kadam *et al.*, 2017).

Table 3. IPNS and foliar nutrition on economics of okra (COBhH-4)

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
T_1 - Control	39800	102800	63000	2.58
T_2 - STCR-IPNS	43726	198500	154774	4.54
T_3 - 100% N through FYM	54600	192000	137400	3.52
T_4 - T_2 + Amino Acids (AA) - Foliar spray (FS)	44026	201800	157774	4.58
T_5 - T_3 + Amino Acids (FS)	54900	199400	144500	3.63
T_6 - T_2 + Micronutrients (MN) (FS)	44618	208000	163382	4.66
T_7 - T_3 + Micronutrients (FS)	55492	204500	149008	3.69
T_8 - T_2 + Aloe vera Leaf Extract (ALE) (FS)	44176	202600	158424	4.59
T_9 - T_3 + ALE (FS)	55050	201500	146450	3.66
T_{10} - T_2 + Moringa Leaf Extract (MLE) (FS)	44326	218000	173674	4.92
T_{11} - T_3 + MLE (FS)	55200	210600	155400	3.82
T_{12} - T_2 + AA +MN + ALE+ MLE (FS)	45968	242400	196432	5.27
T_{13} - T_3 + AA +MN + ALE+ MLE (FS)	56842	231000	174158	4.06

Ascorbic acid

The ascorbic acid content ranged between 9.00 and 13.66 mg 100g^{-1} of fresh fruits. Among the treatments studied, T_{12} and T_{13} treatments recorded higher ascorbic acid content (13.66 and 13.18 mg 100g^{-1} of fresh fruit) which differed significantly among themselves and also over the other treatments. The latter which was found to be comparable with T_6 (12.88 mg 100g^{-1}). The lowest ascorbic acid content was (9.00 mg 100g^{-1}) recorded by control treatment. This could be explained on the basis of better availability of desired and required nutrients in root zone resulting from its solubilization caused by the organic acids produced from the decomposition of organic manures *viz*., FYM. The synthesis of ascorbic acid is closely associated with carbohydrate metabolism. These findings are in agreement with Tripathy and Maity (2009) who recorded highest ascorbic acid content in okra fruits by the application of 50 per cent RDF + BF + organic manure through Neem Cake @ 1.25 t ha^{-1}, by amino acids in Okra (Katharine *et al.*, 2016), FYM + RDF in Okra (Kumar *et al.,* 2017) and by MLE in hollywood plum (Thanaa *et al*., 2017). An increase in ascorbic acid due to the foliar application of boric acid, zinc sulphate and copper sulphate each at 250 ppm was reported by Singh *et al.* (2013) and due to boron in okra by Kadam *et al.* (2017).

Total soluble solids

The highest total soluble solids content of 2.73 per cent was recorded in the treatment that received 100 per cent N through FYM + AA + MN + ALE+ MLE (FS) (T_{13}) followed by T_{12} (2.71%). The effect of moringa leaf extract was found to be superior than aloe vera extract and amino acids. Higher values of total soluble solids by the application of FYM @ 40 t ha^{-1} and micronutrients in tomato (Santosh, 2012) and with amino acid @ 4.0 litre ha^{-1} in okra (Katharine *et al.,* 2016) were reported. The presence of minerals and antioxidants, i.e. proline, phenols, carotenoids and ascorbic acid, other than some osmoprotectants, i.e. amino acids, soluble sugars and K in the moringa leaf extract in addition to phytohormones such as indole-3-acetic acid, gibberellins and cytokinins might be the reason for the enhanced total soluble solids content (Abdalla, 2013).

Mucilage

The application of 100% N through FYM with AA + MN + ALE+ MLE (FS) (T_{13}) recorded the highest mucilage content of 1.74 per cent followed by T_{12} (1.66%). The lowest mucilage content of Okra fruit was registered with the control treatment of (1.12%). The increase in mucilage content might be due to the increase in D-galactose, L.rhamnose and D-galacturonic acid contents in okra fruits by the application of nutrients through organic and inorganic sources (Thirunavukkarasu and Balaji, 2015).

Economics

The cost benefit analysis for Okra as influenced by IPNS and foliar nutrition has been worked out with reference to total cost of cultivation, total return from Okra fruit yield, net return and BCR (Table 3). It ranged from 2.97 to 5.27. The treatment which received the integrated application of STCR- IPNS + AA + MN + ALE+

MLE (FS) (T_{12}) as foliar spray recorded the highest benefit cost ratio of 5.27 which was followed by the treatment STCR-IPNS + MLE (T_{10}) with a benefit cost ratio of 4.92 and T_6 (STCR-IPNS + MN (FS) (4.66). The lowest B: C ratio was registered with the control treatment (T_1) (2.97) where neither fertilizer nor manure was added. Though, the growth and yield parameters and fruit yield were higher in the treatment T_{13} and almost comparable with $T_{12,}$ the cost of cultivation was very high (Rs. 56,842) as compared to T_{12} (Rs.45,968).

In general, the BCR values were higher wherever STCR-IPNS was applied in combination with micronutrients/ amino acids/ aloe vera leaf extract /moringa leaf extract. The next best treatment in terms of BCR to T_{12} was the T_{10} wherein the STCR-IPNS was integrated with moringa leaf extract (4.92) followed by T_6 *viz.,* STCR-IPNS + MN (FS) (4.66). This was in agreement Shahbaz *et al.* (2014) with NPK and organics. The higher cost of cultivation was due to cost incurred for FYM (20 t ha^{-1}). In the treatments wherein STCR-IPNS was involved either alone or in combination, the FYM was applied at the rate of only 4 t ha^{-1}. The difference in the treatment cost made the T_{12} to perform superior than T_{13} and hence, the benefit cost ratio for the treatment T_{12} was higher than the treatment $T_{13.}$

Conclusion

From the present study, it is clearly evident that the application of STCR-IPNS + AA + MN + ALE + MLE (FS) (T_{12}) followed by 100 per cent N through FYM + AA + MN + ALE + MLE (FS) performed better than other treatments with respect to yield parameters, fruit yield and quality of Okra (COBhH – 4). The highest BCR was recorded with STCR-IPNS + AA + MN + ALE + MLE (FS) (T_{12}) followed by the application of STCR-IPNS + MLE (FS) (T_{10}). Therefore, the benefit from the rupees per unit invested was maximum for the application of STCR-IPNS + AA + MN + ALE + MLE (FS) compared to other treatments. Hence, it is concluded that the application of STCR – IPNS with micronutrients (Zn @ 0.5 %; Fe @ 1.0 %; B @ 0.3 %) + MLE + ALE + AA as foliar spray each at 50 ppm thrice on 25, 45 and 60 DAS may be recommended to obtain maximum fruit yield of okra (COBhH-4) with higher net profit and Benefit Cost Ratio.

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