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THE EFFECTS OF SEWAGE SLUDGE APPLICATION ON GRAIN YIELD AND NUTRIENT STATUS OF GRAIN IN TRITICALE UNDER RAINFED CONDITIONS

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ABSTRACT

Eight treatments were used to evaluate the effects of sewage sludge and mineral fertilizer on grain yield and some grain yield componnets, plant nutrient contents and heavy metal concentrations in triticale grain (cv Mikham 2001). The study was conducted using a completely randomized design with 3 replicates in dry conditions in Van, in the East Anatolia region of Turkey in winter cereal cropping season of 2009-2010. Sewage sludge was added to the soil 6 different rates of 5, 10, 15, 20, 25, 30 T ha^{-1} and a single dose of nitrogen and phosphorus fertilizers like as standard dose (80 kg N ha^{-1}+69 kg P ha^{-1}). Moreover, control plot was not added any mineral fertilizer or sewage sludge. According to study results, the highest sewage sludge rate resulted in 99 % higher grain yield compared to control. Moreover the highest sewage sludge rate were obtained 20 % more grain yield than mineral fertilizer. The obtained results show that the grain triticale took distinctly more macroelements under the influence of sewage sludge in comparison with the control. Additionally grain mineral concentrations such as N, P, Mg, Zn, Fe were significantly affected with increasing of sewage sludge rates. In contrast, other nutrients (K, Mn, Al, Ni, Cu, Cd, Pb, Cr) was not affected significantly the increasing of sewage sludge rates. It is concluded that, 30 T ha^{-1} sewage sludge rate could be substitute for commercial fertilizer for having optimum plant growth of triticale in marginal lands.

KEYWORDS:
Triticale, plant nutrient, heavy metal, grain yields.

INTRODUCTION

Triticale (×*Triticosecale*), is a hybrid of wheat (*Triticum*) and rye (*Secale*). Triticale is used for different purposes, in particular for feed as grain. Triticale is used both human and animal feedings; and having higher yield over other cereals such as wheat and barley in marginal lands. Therefore in triticale breeding program is aimed to new tolerant varieties for marginal areas (acidic or alkali soils), micro mineral deficiencies (cooper, zinc or magnesium) or toxicity (boron) and drought in the world [1]. Moreover triticale is more efficient than other cereal species in the annual precipitation rate low and arid conditions without irrigation facilities, is a type of cereal to be an alternative to these regions [2].

Sewage sludge can be used to the increased the yield of triticale grown in marginal areas and due to low cost. Because of sewage sludge contains many macro and micro minerals and organic matter can substitute for commercial fertilizers and organic matter if applied in the right amounts to soil. Besides [3], reported that applying organic materials to crop soil not only generates a better nutritional state but furthermore increases soil aeration and the water holding capacity of the soil. In general, concentrations of essential elements in plants grown on sludge were similar to concentrations of elements in plants grown with inorganic fertilizer. [4], demonsrated that the beneficial effects of using sludge in agriculture. It has been shown that sewage sludge application improves the physical, chemical, and biological properties of soil [5]. Nutrients contained in sludge increase plant biomass and yield [6].

Main problems of an excessive application of sewage are plant toxicity due to accumulation of heavy metals in soils. However, the heavy metal content of sewage sludge might be very variable depending on its origin and processing applications. However, the heavy metal content of sewage sludge might be very variable depending on its origin and processing applications [7]. There might be an increase in the heavy metal content of sewage sludge with a heavy industry nearby the urban areas. [8] reported that that sewage sludge applied to apple trees did not cause toxicity in the leaves. Even so, metals in sewage sludge are generally organically bound and therefore less available for plant uptake than the more mobile metal salt impurities found in commercial fertilizers [9, 10]

The objective of this study, due to soils in our region are fairly low in organic matter content (generally about 1%) and the soil has medium phosphorus, low nitrogen and low alkaline; this study was planned and executed to examine different application rates of sewage sludge and the effects on triticale grain yield and plant nutrient contents in grain.

MATERIALS AND METHODS

Materials. The study was conducted as a field experiment on a research area at located in the Eastern Anatolia region of Turkey (38º-55' N; 42º – 05' E, 1725 m above sea level). Triticale variety Mikham-2001 was used as a plant material. Triticale was selected as the test plant because of the current concern for environmental tolerance according to other cereals, moreover it has higher yields in poor soil conditions.

Methods. Sewage sludge were applied to triticale to supply organic matter, macronutrients and micronutrients. Field experiments were conducted in 2009-2010 in winter growing seasons. The experimental design was a randomized complete block with three replications with a total number of 24 plots. Area of each plot was 6 m^2 (1. 20 m X 5 m each one). The plots were ploughed one year ago in spring season. Second ploughing was done in opposite directions before planting on early September. Sewage sludge was added to the soil 6 different rates of 5, 10, 15, 20, 25, 30 T ha^{-1}. And an other treatment was applied as a single dose of nitrogen and phosphorus fertilizers (80 kg N ha^{-1} +69 kg P ha^{-1}) that was standart dose for triticale. Control plot was not applied any sewage and mineral fertilizer. Sewage sludge was applied with a hand and mixed into the top 1-5 cm of soil. Sewage sludge applications were completed before 30 day seeding time. Mineral fertilizer plots were fertilized at seeding time with 150 kg DAP (Di-Ammonium Phosphate) ha^{-1} (N 18%-P 46%), and 250 kg AS (Ammonium Sulphate) ha^{-1} (N 21%) was applied as a top dressing before ear emergence. Triticale was sown on October 20, 2009. Seeds were hand-drilled at depths of 5 cm (4-5 cm) and spaced approximately 1 cm apart along each row at a rate of 100 seeds per meter. The distance between each row was 20 cm (500 seeds m^{-2}). Each plot was sown 2 meters away each other due to limit the mixing of treatments. All plots were weeded twice by hand during triticale growing season. No irrigation was provided at any time. No insects, pests, or disease infestations were observed.

Plant Measurements. Triticale plots were harvested in the beginning of July, 2010. Plant height was measured as the height of the tallest culm of approximately 15 plants from the soil surface to the tip of the spike, awns excluded. Fertile spike density was measured by hand cutting the above-ground portion of plants from the center of the middle row in each plot just prior to harvest and determining the number of fertile spikes per meter. The sample unit consisted of 15 plants harvested from three randomly selected samples from the two middle rows of each plot, at grain maturity. Harvested plants were then stored in a low-humidity room for seven days. Kernels were threshed by hand, and kernels $spike^{-1}$ and kernel weight $spike^{-1}$ were calculated based on spike. Grain yield (T ha^{-1}) was determined by harvesting grain in a paper bag, and weighing it on a digital scale accurate to 0.1 g. 1000 grain weight determination, 1000 grains randomly selected samples from the harvested grain from plots were counted and weighed on a digital scale accurate to 0.1 g.

Soil, Sewage Sludge and Plant Nutrient Status of Harvested Grain Descriptions

For the analysis of grain the nutrients and heavy metals were dissolved in 3 N HCl after the organic matter had been ashed in a furnace at 500 ^{0}C. The N content of plant samples was determined by the Kjeldahl method [11]. Phosphorus was measured by spectrophotometer. K, Mg, Fe, Mn, Cd, Cr, Ni, Cu, Pb and Zn contents were determined using flame atomic absorbtion spectrophotometry.

Dried sewage biosolid was obtained from the Campus of Yuzuncu Yıl University Waste Water Unit. Sewage sludge samples were air dried. Organic matter in sewage sludge was measured by the dry combustion method [12]. Sludge NH4 _ N was determined by extraction in 2 M KCl [13]. Total P in sludge was measured spectrophotometrically. Total metals in sludge were determined using flame atomic absorbtion spectrophotometry following extraction by nitric-hydrochloric acid digestion [14]. The sewage sludge has high organic matter, low pH and rich all macro and micronutrients (Table 1).

The Experimental soil analysis has been described in detail by [11]. Soil structure analysed as [15]; soil pH was described as [16] total organic matter as [17], phosphorus was determined as [18], the N content of seed samples digested in concentrate sulfuric acid was determined by the Kjeldahl method, total metal as [14]. The soil samples were taken from the surface horizon of experiment area. The physical and chemical characteristics of the sewage sludge and soil are shown in Table 1. The soil has sandy-clay loam texture and low organic matter and nitrogen, rich

TABLE 1
Mean analytical characteristics of soil, sewage sludge in the experiment (dry weight basis).

Properties	0-20 cm	20-40 cm	Sewage sludge
Texture	Clayey-loam	Clayey-loam	Organic material
CaCO3 (%)	4.7	4.9	5.8
pH	8.20	8.19	6.55
EC mS cm-1	2.76	2.66	3.42
Org. Mad (%)	0.98	0.81	45.5
P (ppm)	6.79	5.51	2120.5
N (%)	0.069	0.057	1.30
K (ppm)	214	229	2589.3
Ca (ppm)	1459	1871	9856.3
Mg (ppm)	149	181	4985.6
Cu (ppm)	1.00	1.15	10.9
Zn (ppm)	0.60	0.60	250.5
Fe (ppm)	6.93	7.52	15.7
Mn (ppm)	26.8	28.1	68.5
Ni (ppm)	0.329	0.444	75.5
Cd (ppm)	0.056	0.056	0.355
Pb (ppm)	0.601	0.576	0.895
Cr (ppm)	0.20	0.22	95.2

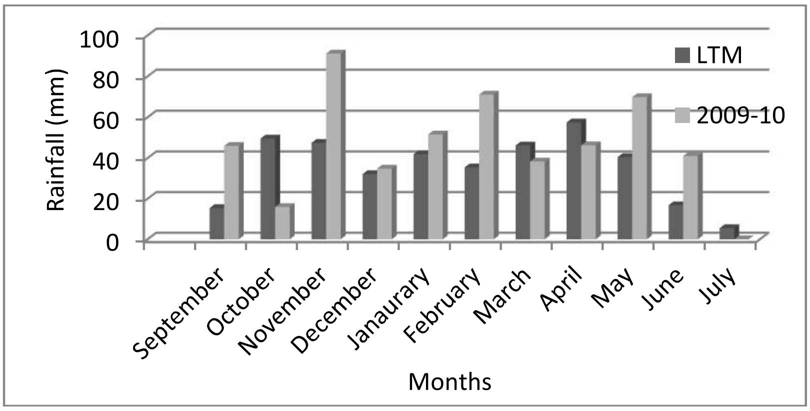

FIGURE 1
Rainfall datas of Van province in 2009-2010 years and long term Months (LTM)

potassium and lime content medium phosphorus and is low alkaline.

Climatic Descriptions. The rainfall data of the region are represented in Figure 1. Temperate climatic condition is ruled in the region. During the course of experiment, from October to July in 2009-2010 years, rainfall was high during the autumn and winter months, which is important for recharging soil water. Amount of the rainfall was quite different over long term period.

Statistical Analysis: The data were statistically analyzed by MSTATc and comparative analyses of the means were performed by LSD Test using the MSTATc Programme.

RESULTS

Grain Yield and Some Grain Yield Components. In the current study, the sewage sludge effects on some plant growth parameters were investigated. Table 2. shows the effects of sewage sludge rates and mineral fertilizer separately on number of fertile spike per square meter, spike height (cm), number of kernel per spike, kernel weight per spike, grain yield (T ha^{-1}), 1000 seed weight (g). Sewage sludge significantly increased spike height (cm), number of kernel per spike, kernel weight per spike, grain yield (T ha-1), 1000 seed weight (g) in comparison to control and mineral fertilizer treated triticale. The most significant increases in number of fertile spike were obtained from the highest sewage sludge rate (30 T ha^{-1}) with 337.7 number of fertile spike. The control dose added any minerals have the lowest number of fertile spike. Each added dose of sewage sludge has led to a significant increase in number of fertile spike. Even, 10 ton ha^{-1} of sewage sludge treatment has been as effective as standard mineral fertilizer application on number of fertile spike. Moreover similar effects of sewage sludge were obtained on spike height (cm). The most significant increases were obtained with the highest application of sewage sludge doses (20 T ha^{-1} and 30 T ha^{-1}). Moreover, sewage sludge of 15 T ha^{-1} dose can be replaced a single dose of mineral fertilizer (80 kg N ha-1 +69 kg P ha-1). Number of kernel per spike and kernel weight per spike were affected significantly with increasing sewage sludge rates. The most increases in number of kernel per spike and kernel weight per spike were obtained with the highest sewage sludge rates (25 T ha^{-1} and 30 T ha^{-1}). It was found that application of sewage sludge appeared to be more beneficial for the yield components and grain yield of triticale than mineral fertilization. With different sewage sludge rates and standart dose of chemical fertilizers of this study on grain yield of winter sown triticale were significantly different ($p<0.01$) (Table 2). Grain yields were found between 1.74 and 3.49 T ha^{-1} according to application affects. The best effects of sewage sludge were obtained on grain yield (3.49 T ha^{-1}) from the 30 T ha^{-1} sewage sludge rate. The lowest grain yield was determined from the control treatment as 1.74 T ha^{-1}. In this study, standart dose of nitrogen and phosphorus fertilizer for triticale gave lower grain yield (3.13 T ha^{-1}) compared to the highest sewage sludge. Moreover 15 T ha^{-1} sewage sludge dose can be used to instead of a single dose of nitrogen and phosphorus fertilizers. The highest sewage sludge rate resulted in 99 % higher grain yield compared to control. Moreover the highest sewage sludge rate were obtained 20 % more grain yield than of standart dose of mineral fertilizer. Sewage sludge added plots have higher number of fertile spike per square meter, this may be, sewage sludge improved soil conditions like as soil water capacity. Commonly, marginal lands due to having less organic material in soil has low nitrogen and low water holding capacity. Adequate amount of sewage sludge added to soil reduced the soil evaporation and helped to keep soil more moist due to its high organic matter content. Sewage sludge application development features of the soil has increased the number of spike per square meters. In this case, grain yield is due to a strong correlation between the spike in the number of square meters [19]. Therefore the increase in the number of fertile spikes per square meter increased grain yield. Additionally sewage sludge application on triticale was more favorable on grain yield and yield componets. Many current researches were demontsrated on the effects of sewage sludge on the grain yield. These researches were showed that sewage sludge improved the plant growth and soil characteristics due to the its high organic matter and adequate macro minerals contents. [7,20]. Especially [21], reported that sewage sludge was quite enough for optimum plant growth of sorghum. Another study, sewage sludge were found that have a significant effect on all wheat yield components. And it was reported that 20 T ha^{-1} of sewage sludge application could be recommended the suitable dose for the wheat [22]. [23], also reported highest increase in the grain yield of wheat and total dry matter yield treated with sewage sludge. Sewage sludge significant positive effects on yield components and grain yield were obtained.

Protein Ratio. The protein content in grain dry matter varied between 12.08 and 13.95 % (Table 3). Statistical analysis of data confirmed that the protein content was significantly affected by the treatments. The highest content (13.95 %) was assessed in 15 T ha^{-1} sewage sludge rate. The subsequent doses of sewage sludge rates yielded similar results in protein ratio. The lowest protein content (12.08 %) was found in the control plots. Sewage sludge affected positively grain protein content due to sewage sludge rich in nitrogen mineral. It can be observed that the contents of total nitrogen in the soil increased when the sewage sludge added, the largest values of total nitrogen being recorded when the sludges was applied than the mineral fertilizer. Grain protein ratio was obtained with 13.33 % from inorganic nitrogen fertilizer aplication. This results show that sewage sludge application was more effective than nitrogen fertilizer on protein ratio.

Nutrient and heavy metal contents. The effects of sludge rates and a single dose of N- P fertilizer levels on N, P, K, Mg, Mn and Zn contents of grain are shown in Table 3. The application sewage sludge resulted in the largest increase of nitrogen contents in grain. The sewage sludge added soils particularly those to which high doses of sludge (30 t ha^{-1}) had been applied showed a higher nitrogen content in comparison to control. [21], reported that N uptake increased from with the highest biosolid application rate. And same researchers point out that Sludge application increased N uptake than inorganic fertilizer. [24], reported that plant N uptake increased with sewage sludge application and N fertilization. The results when evaluated for phosphorus content, grain phosphorus was affected significantly more with a single dose of phosphorus in comparison to all sewage sludge rates and control. In other words the highest grain P concentration was obtained with added to soil P mineral fertilizer. Additionally, sewage sludge effects were highly significant on P concentration in comparison to control dose. [25], reported that N and P contents in fruits of tomato

TABLE 2
Effects of Different Doses of Sewage Sludge and Chemical Fertilizer on Number of Fertile Spike per m^{-2}, Spike Height (cm), Number of Kernel Per Spike, Kernel Weight Per Spike, Grain Yield (T ha^{-1}), Thousand Seed Weight (g).

Treatments		Number of fertile spike per m^{-2}	Spike Height (cm)	Number of Kernel per Spike	Kernel Weight Per Spike	Grain Yield (T/ha)	1000 seed weight (g)
Control		250.0 f	6.1 e	20,6 d	0,65 e	1,74 f	30,3 b
Inorganic Fertilizer (N and P)		279.7 e	8.5 bc	31,6 a	1,05 bc	3,13 cd	34,0 a
Sewage sludge	5 T/ha	265.0 e	6.8 d	28,3 c	0,86 d	2,35 e	30,1 b
	10 T/ha	285.0 d	8.1 c	28,6 bc	0,97 cd	2,92 d	31,6 b
	15 T/ha	299.7 c	8.8 ab	30,6ab	1,12 ab	3,20 bc	35,0 a
	20 T/ha	313.3 b	9.3 a	30,6 ab	1,18 ab	3,38 ab	35,0 a
	25 T/ha	318.3 b	8.8 ab	31,6 a	1,20 a	3,43 ab	35,3 a
	30 T/ha	337.7 a	8.8 ab	31,6 a	1,21 a	3,49 a	35,6 a
LSD (P<0.05)		11.82	0.593	2.163	0.135	0.235	1.817
F values		59.72**	32.09 **	27.10**	18.84 **	62.37**	14.84**

* P < 0.05; ** P < 0.01; ns: not significant; different letters indicate means significantly different (Least Significant Difference test)

plant were increased by the increasing applications of sewage sludge rates.

Concentrations of the studied macronutrients K and Mn showed no differences between sewage sludge and a single dose of standart fertilizer (N, P) in triticale. Moreover, all sewage sludge rates and a standart dose of mineral fertilizer gave similar results. Additionally, grain K and Mn contents were not higher in sludge and in mineral fertilized plots in comparison to control plot. This may be attributed to adequate K and Mn contents of the experimental soil for optimum plant growth. Similar result was pointed out by [6] and they found that sewage sludge application did not affect K levels of plant tissue.

Zinc, magnessium and iron contents were investigated in this study, and concentrations of these nutrients were significantly effected with the increasing of sewage sludge rates. The highest rates of sewage sludge was more effective rate on concentrations of these nutrients. Although, the standard mineral fertilizer application more efficient than the control, but similar results were obtained between sewage sludge treatment and mineral fertilizer application (Table 3, 4). Similar results were found by many researchers. [7], point out that the increasing of the Zn concentration of maize was also observed with increasing sewage sludge rates. The increase of Zn in plant tissue might be due to its mobility and bioavailability [26]. [25], reported that Mg in fruits of tomato plant were increased by the increasing applications of sewage sludge rates.

Grain Aluminum (Al), cadmium (Cd), chromium (Cr), nickel (Ni), lead (Pb), copper (Cu) contents were unaffeted by using sewage sludge and mineral fertilizer (Table 4). The results of aluminum (Al) concentration in grain were similar with all sludge rates and control. Moreover it changed between 14.9 and 54.9 ppm insignificantly. The effects of sewage sludge and mineral fertilizer on aluminum concentration was higher than control. Even though these differences were not significant. Cadmium (Cd) concentration in grain changed between 0.505 and 0.547 ppm. Concentrations of this nutrient was unsignificantly effected with the increasing of sewage sludge rates and mineral fertilizer. The highest grain chromium content (1.67 ppm) was obtained with mineral fertilizer. However, there was no significant difference between sludge treated plots and inorganic N and P treated plots on chromium concenration. Nickel (Ni) concenration was investigated in this research, and there was no significantly differences in nickel concentration with the using of sewega sludge and inorganic N-P fertilizer compare to control. Lead (Pb) and copper (Cu) contents were increased by sewage sludge application compared to control and nitrogen and phosphorus fertilizers, but there was no significantly differences in Lead (Pb) and copper (Cu) concentrations of grain.

In the present study, results revealed that nutrient contents increased in dry matter, especially Zn and Fe with increasing sludge application rate, but grain heavy metal contents were unaffected. [27], reported that application of sewage sludge or compost did not increase heavy metal concentrations in corn grain with respect to inorganic fertilizer. These trace metals, which are difficult to remove, are the most significant restraint relative to land application of sludges and can often negate the benefits of land application. Even so, metals in sewage sludge are generally organically bound and therefore less available for plant uptake

TABLE 3
Effects of Different Doses of Sewage Sludge and Chemical Fertilizer on grain Protein Ratio (%) and Grain Mineral Concentration such as Nitrogen (%) Phosphorus (ppm), Potassium (ppm), Magnesium (ppm), Manganese (ppm), Zinc (ppm)

Treatments		Seed Protein Ratio (%)	Nitrogen (%)	Phosphorus	Potassium	Magnesium	Manganese	Zinc
Control		12.08 c	1.93 c	3.31 c	1.00	0.246 bc	46.46	19.67 c
Inorganic Fertilizer (N P)		13.33 ab	2.13 ab	4.99 a	1.07	0.292 ab	52.26	24.17 b
Sewage sludge	5 T/ha	12.70 bc	2.03 bc	4.06 b	1.05	0.300 ab	50.97	25,74 ab
	10 T/ha	13.33 ab	2.13 ab	4.44 ab	1.01	0.301 ab	45.83	24,61 ab
	15 T/ha	13.95a	2.23 a	4.26 b	0.96	0.257 abc	47.46	24,44 ab
	20 T/ha	13.74 a	2.20 a	4.42 ab	0.96	0.219 c	46.48	24,64 ab
	25 T/ha	13.75 a	2.20 a	4.19 b	1.05	0.304 a	46.55	24,02 b
	30 T/ha	13.74 a	2.23 a	4.52 ab	1.00	0.279 ab	46.75	26,87 a
LSD (P<0.05)		0.936	0.135	0.702	ns	0.060	ns	2.566
F values		4.310*	5.40 **	4.24**	ns	4.576**	ns	6.058**

* P < 0.05; ** P < 0.01; ns: not significant; different letters indicate means significantly different (Least Significant Difference test)

TABLE 4
Effects of Different Doses of Sewage Sludge and Chemical Fertilizer on Grain Mineral Concentration such as Iron (ppm), Aluminum (ppm), Cadmium(ppm), Chromium(ppm), Nickel (ppm), Lead (ppm), Copper (ppm).

Treatments		Iron	Aluminum	Cadmium	Chromium	Nickel	Lead	Copper
Control		59.1 d	14.9	0.505	0.90	1.29	0.146	8.15
Inorganic Fertilizer (N P)		77.6 ab	57.4	0.547	1.67	2.26	0.045	8.18
Sewage sludge	5 T/ha	72.7 bc	21.3	0.538	1.09	1.66	0.205	8,44
	10 T/ha	64.7 cd	17.7	0.526	1.32	1.62	0.061	8,21
	15 T/ha	71.8 bc	20.3	0.532	1.08	1.59	0.189	8,63
	20 T/ha	76.9 abc	21.2	0.518	1.02	1.50	0.129	8,81
	25 T/ha	86.2 a	28.9	0.544	1.30	1.58	0.110	8,52
	30 T/ha	84.1 ab	21.5	0.520	1.26	1.65	0.493	8,57
LSD (P<0.05)		12.480	ns	ns	ns	ns	ns	ns
F values		4.949**	ns	ns	ns	ns	ns	ns

* P < 0.05; ** P < 0.01; ns: not significant; different letters indicate means significantly different (Least Significant Difference test)

than the more mobile metal salt impurities found in commercial fertilizers [9,10,21].

DISCUSSION AND CONCLUSIONS

It is concluded that 30 t ha^{-1} rate that the highest dose of this study resulted in 99 % higher grain yield in comparison to control. Moreover the highest sewage sludge rate were obtained 20 % more grain yield than mineral fertilizer. Therefore, 30 T ha^{-1} sewage sludge rate could be substitute for commercial fertilizer for having optimum plant growth in triticale. It is recommended that sewage sludge may be used as N, P Mg, Zn, Fe sources. Marginal lands like a low input soils can be reorganized with using sewage sludge. The using of sewage sludge are a risk for heavy metal contamination in soil, therefore short term uses may be recommended.

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