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Original Research Article

Effect of Iron, Zinc and Boron on Sugar Beet Yield and Quality

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Abstract: An experiment was conducted in Khoy as split factorial based on complete random block design in three iterations. In order to study the effect of iron(Fe), zinc(Zn), and boron(B) on the yield and quality of sugar beet. Experimental treatments included the use of Fe as main terrace at three level (0,75 and 150 Kg/ha) and Zn at two level (0 and 100 Kg/ha) and B at two level (0 and 20 Kg/ha) as secondary terrace. The interaction between Fe and Zn were also significant on the impurity rate of harmful nitrogen and the interaction between Fe and B were significant on the sugar yield and the impurity rate of harmful nitrogen. The interaction of zinc and boron was also significant on the root performance, the impurity rate of harmful nitrogen, and the purity of the raw syrup and Alkalinity. Iron, Zinc and boron had significant effect on Alkalinity and sugar content in malasses. The maximum root yield was obtained by using 100 and 20 kg/ha of zinc and boron, respectively. The maximum rate of purity of the raw syrup was obtained by using of Zinc with 20 kg/ ha of Boron. The maximum rate of impurity in harmful nitrogen was obtained by using 150 kg/ha of Iron and nonuse of Zinc. They highest percentage of Alkalinity was obtained with 150 kg/h iron, 100 kg/h Zinc and 20 kg/h of Boron. The results showed that the quantitative and qualitative yield of sugar beet has increased by using the micro nutrient elements.
Keywords: Fe, B, Ze, Sugar Beet.

INTRODUCTION

Sugar beet is an industrial and strategic plant for sugar production in the country. The by-products are sugar beet, molasses and pulp. A large amount of alcohol can be produced from the fermentation of molasses, and its residue contains sugar, cellulose and nitrogenous substances, which are used in feeding and supplying fodder to animals (Abdollahian *et al*., 2005). Sugar beet with its scientific name (Beta vulgaris L.), is a biennial plant, belonging to the family of sphingos and is cultivated annually (Jozi and Zare Abianeh, 2015). Sugar beet, as the second crop for sugar production, is planted on an area equal to 7 million hectares in 48 countries of the world (Annonymus, 2014). Since sugar, as the main product of sugar beet, provides a major part of the energy needed by humans, the agricultural management and production strategy of this plant is evaluated based on the percentage of extractable sugar per unit area. Adjusting the appropriate growth conditions to achieve maximum sucrose is possible in two ways (Rahimi and Arsalan, 2012), increasing the amount of raw product based on root yield and increasing product quality by increasing the percentage of sucrose and reducing harmful substances such as nitrogen. Sodium and potassium in syrup. One of the important and effective factors in product performance and quality is plant nutrition management (Honarvar *et al*., 2012). In the proper nutrition of the plant, not only every element must be sufficiently available to the plant, but also it is important to create a balance and observe the balance between the consumed elements, because in the condition of nutritional imbalance, by adding a number of nutritional elements, in addition to not increasing the yield, Disturbances are also created in the growth of the plant and finally the yield is reduced (Malakouti *et al*., 2007). For this reason, today, in order to increase the yield of agricultural plants and improve their quality, the tendency to use low-consumption elements has spread (Alam *et al*., 2007). Most of Iran's soils are calcareous, in these soils the nutrition of low consumption elements is very important and it is relatively difficult to supply these elements, and due to the low consumption of fertilizers containing low consumption elements in the past in fertilizer recommendation programs, erosion, leaching, Indiscriminate use of chemical fertilizers containing

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high-consumption elements and the use of high-yielding modified cultivars as well as failure to observe crop rotation and as a result the increasing harvest of the reserves in the soil have all caused a decrease in the reserves of these elements in the soil so that in different parts of the world, Plants show a positive reaction to the application of fertilizers containing low-use elements (Malakouti *et al*., 2007). In plants, the lack of low-use elements leads to many limitations in metabolic and physiological processes, even though plants need low amounts of these elements, therefore, in order to increase the production of agricultural plants with high quantity and quality, fertilization of low-use elements It is essential. Iron, as one of the essential nutritional elements of plants, increases the performance and quality of plants by increasing the amount of chlorophyll and the amount of carbohydrates. Also, iron acts as an electron acceptor and activator of several electron transfer enzymes in photosynthesis (Irmak *et al.*, 2012).

Zinc is the second most abundant metal element in plants after iron, which acts as a metal part of enzymes or functional structural part and cofactor of many enzymes and is required for chlorophyll production, pollen production, fertility and germination (Honarvar *et al*., 2012). The lack of proportional application of nutritional elements will lead to irreparable damage to soil fertility and a decrease in the intrinsic amount of low-use elements in soils around the world (Amin *et al*., 2013). In the analysis of the effect of fertilizers containing low consumption elements of iron, zinc and boron on the quality of sugar beet, it was reported that with two foliar applications at 60 and 75 days after planting, the root yield was 86 tons per hectare (Malakouti *et al*., 2009). The results of experiments conducted on low-use elements in the sugar beet plant have also shown that the use of fertilizers containing low-use elements has significant effects on the nutritional status of this plant (Grazebiesz *et al*., 2010). Among the low-use elements, boron is more important in sugar beet cultivation. In an experiment with the consumption of boron in sugar beet, it was concluded (Gangvar and Srivastava, 2009) that the consumption of 0.5 mg of boron per kilogram Its soil or foliar application with a concentration of 0.2%, once during its growth period, increased root yield, root to shoot ratio, root sugar, leaf surface index and boron absorption. Abdolhadi reported an increase in yield between 1 and 51% by spraying iron, zinc and manganese in several crops, including sugar beet (Abdolhadi, 1986). In the investigation of the effect of foliar application of low consumption elements boron and iron on the quantity and quality of sugar beet in Kurd city, it was concluded (Rayisi Nafchi *et al*., 2014) that high root yield and sugar yield were obtained from the foliar application method of two elements. Sugar beet is one of the important and strategic products of the country and West Azarbaijan province is one of the major production centers of this product. Therefore, the purpose of this research is to investigate the effect of iron, zinc and boron on root yield and some quality indicators of sugar beet.

MATERIALS AND METHODS

This research was carried out in 2016 at the Agricultural Jihad Research Center of Khoi city with a latitude of 38 degrees and 32 minutes and a longitude of 44 degrees and 55 minutes with an altitude of 1139 meters above sea level. The soil of the test site had a clay-loam texture with pH=78.78 (Table 1). The experiment was conducted as a split factorial based on a randomized complete block design in three replications. The experimental treatments include the low consumption elements of iron sulfate at three levels at zero (Fe1), 75 kg/ha (Fe2) and 150 kg/ha (Fe3) and zinc sulfate at two levels at zero (Zn1) and 100 kg/ha (Zn2) and boric acid were used in soil at two levels of zero (B1) and 20 kg/ha (B2) before planting. According to the results of soil analysis, 100 kg of triple superphosphate, 100 kg of potassium sulfate and 300 kg of urea were used per hectare. So that half of the nitrogen fertilizer used was used during planting and the other half was used in the six- to eight-leaf stage of the plant, and all the phosphate fertilizers and half of the nitrogen fertilizer were mixed with the soil along with plowing. At the end of the growing season in October, after removing one meter from the beginning and end of the rows and the marginal rows of each plot, from the middle four rows of each plot, harvesting was done at the level of 4 square meters. By weighing the harvested roots per unit area, the root yield was calculated in tons per hectare. 12 kg samples were prepared from each plot and taken to determine the percentage of sugar, nitrogen, potassium and sodium. After complete washing, a paste was prepared from the roots obtained from sampling and immediately placed in the freezer. Then these frozen samples were analyzed to measure the quality characteristics by Betalyzer model 3016-D and film photometer.

Table 1: Physico-chemical properties of the soil used in the experiment

Depth	Soil texture	EC_e (dS.m^{-1})	%						pH	mg kg^{-1}				
			Clay	Silt	O.C	N	CCE	SP		K	P	Fe	Zn	B
0-30	SL	1.29	21	23	1.1	0.01	11.3	34	7.8	319	10.2	5,6	0.85	0.77

To obtain the amount of sugar in molasses, equation (1) was used (Dutton and Bowler, 1984)

$$\% MS = 0.343(K + Na) + 0.094(amino\text{-}n) – 0.29 \quad \ldots\ldots\ldots (1)$$

In this MS equation: the amount of sugar in molasses, K, Na and amino-n are the amounts of harmful sodium, potassium and nitrogen in molasses in terms of milliequivalents per hundred grams of sugar beet roots. The sugar yield was obtained using the equation (2) below.

SY=%SC*%RY …………………… (2)

In this regard, SY is sugar yield, SC is true, and RY is root yield. Alkalinity, which is one of the quality characteristics of sugar beet roots, was calculated based on the amount of nitrogen, sodium and potassium elements using equation 3 (Sheikh Aslami, 2002). (3) ALC=$\frac{K+Na}{N}$

Another important factor in the quality of beet sugar is the degree of purity of the syrup, which is usually expressed as a percentage and is the ratio of pure sugar to impure sugar. Data variance analysis was done by minitab14 statistical software and mean comparison was done by Duncan's method at 5% level.

RESULTS AND DISCUSSION

Root function

The results of variance analysis of experimental data showed that the effect of experimental factors on this trait was significant. In the analysis of interaction effects, only the interaction effect on and on was significant (Table 2).

Table 2: Analysis of variance of traits

Source of variation	Degree of freedom	Root yield	Sugar yield	Purity of raw syrup	Harmfull nitrogen	Alkality	Molasses
Replication	2	3.989	0.588	50.008	0.043^{ns}	0.831ns	0.143^{ns}
Fe	2	388.901**	10.113**	21.296ns	0.710*	5.65**	0.142^{ns}
Error	4	6.960	0.249	7.552	0.061	0.143	0.055
Zn	1	200.081**	4.906**	123.951**	0.384**	14.314^{ns}	0.449^{ns}
Fe$_{\times}$Zn	2	3.576^{ns}	1.035^{ns}	6.094^{ns}	0.508**	2.492ns	0.379^{ns}
B	1	246.333**	7.462**	8.468^{ns}	1.013**	10.628^{ns}	0.336^{ns}
Fe× B	2	2.277^{ns}	1.705*	21.72^{ns}	0.313**	2.664^{ns}	0.05^{ns}
Zn×B	1	16.335*	0.232^{ns}	130.188**	0.157*	18.29*	0.253^{ns}
Fe×Zn×b	2	1.113^{ns}	0.878^{ns}	30.524^{ns}	0.103^{ns}	23.164**	0.689**
Error	12	3.196	0.423	14.725	0.033	3.326	0.114
(CV%)		3.09	7.67	5.21	14.91	14.05	10.25
**, *, ns: are significant difference in 1 and 5 percent and non-significant, respectively.							

According to the table comparing the averages among the levels of iron used, the highest root yield with an average of 63.18 tons per hectare is related to the consumption of 150 kg per hectare of iron sulfate and the lowest is related to the absence of iron sulfate consumption with an average of 51.83 tons per hectare (Table 3).

Table 3: Mean comparison of main effects in traits

Trait factors	Root yield	Sugar yield	Purity of raw syrup	Harmfull nitrogen	Alkality
Fe(kg/ha)					
control	51.83c	7.42b	73.18	0.96b	13.03ab
75	58.34b	8.90a	75.19	1.44a	12.26b
150	68.18a	9.09a	72.67	1.27a	13.63a
Zn(kg/ha)					
control	55.43b	8.10b	75.54a	1.32a	12.35
100	60.14a	8.84a	71.82b	1.12b	13.61
B(kg/ha)					
control	55.17b	8.02b	73.20	1.39a	12.43
20	60.40a	8.93a	74.17	1.05	13.52
Means in a column of each treatment followed by the same letter are not significantly different at *P≤0.05*.					

Comparison of the average interaction effect of zinc and boron showed that the highest yield with an average of 63.44 tons per hectare was related to the consumption of 100 and 20 kg per hectare of zinc sulfate and boric acid, respectively .The use of iron sulfate increased the yield of sugar beet roots in this experiment. In Mazlumi *et al*.'s experiment (Mazlumi *et al*., 2012), the application of iron sulfate also produced optimal root yield, biomass and sugar. Yarnia and colleagues (Yarnia *et al*., 2008) showed that the application of iron, zinc and boron elements causes a significant increase in sugar beet root yield, so that a 34% increase in the root yield of the plants that are associated with foliar application of low-consumption elements achieved. They related the reason for the increase in root performance with the consumption of low-use elements to the increase in chlorophyll pigments and the photosynthetic capacity of the plant.

Mostafa and colleagues (Mostafa *et al.*, 2011) concluded that the application of low consumption elements significantly increased the length, diameter, fresh weight and root yield.

Sugar performance

The results of variance analysis of the experimental data showed that the main effect of iron, zinc, and boron on sugar yield was significant (Table 2). According to the comparison test of average traits, among the levels of iron used, the highest sugar yield with an average of 9.098 tons per hectare is related to the consumption of 150 kg per hectare of iron sulfate, and the lowest one is related to the absence of iron sulfate consumption with an average of 7.42 tons per hectare (Table 3). Examining the interaction effects showed that there is a significant interaction between iron and boron ($p<0.05$) (Table 3). Other interaction effects on this trait were not significant. Comparison of the average effect of iron and boron showed that the highest sugar yield with an average of 9.82 tons per hectare was related to the consumption of 150 and 20 kg per hectare of iron sulfate and boric acid, respectively. The results of Amin *et al.*'s research (Amin *et al.*, 2013) showed that the sugar yield increased from 8.64 tons per hectare in the control treatment to 8.79 and 9.17 tons per hectare with one and two foliar sprays of low consumption elements, respectively. Increased Yarnia *et al.*, (2008) also reported that the use of low consumption elements caused a 46% increase in sucrose yield compared to the control treatment. Foliar spraying of low-use elements increases the surface of the plant's green cover, and as a result, leaf growth increases and facilitates the transfer of water to the vessels. On the other hand, boric acid plays an important role in the transfer of sugar substances, regulation of cell metabolism, the amount of potassium and calcium in the plant, the growth of primary cells, pollination and the regulation of water required by the plant, all of which can be correlated with the production and accumulation of sugar in sugar beet (Camberato, 2004). Sugar yield, as the most important component in sugar beet production, is influenced by root weight and sugar percentage. Several factors are effective on the quantity and quality of sugar beet root yield, among them are cultivar, type of weather and climate, planting and harvesting time, soil fertility and plant nutrition, especially the type of fertilizer, amount and time of fertilization and management and Irrigation planning mentioned (Baradaran Firoozabadi, 2002).

Purity of raw syrup

Examining the variance analysis table of experimental data showed that the main effect of zinc on the purity of raw syrup was significant (Table 2). The comparison of the average traits also showed that among the levels of zinc, the highest purity percentage of raw syrup with an average of 75.54% was obtained in the first level without the use of zinc sulfate (Table 3). Examining the mutual effects of the studied factors also showed that there is a significant mutual effect between zinc and boron (Table 2). The comparison of the average interaction between zinc and boron showed that the highest purity of raw syrup with an average of 77.93% is related to the non-use of zinc sulfate and the use of 20 kg/ha of boric acid . Based on the results, the use of low-use elements has significantly increased the purity percentage of raw syrup compared to their non-use. Decreasing the degree of syrup purity causes an increase in sugar waste in the form of molasses (Heidari, 2011). Based on the results obtained in this research, the use of low consumption elements has significantly increased the purity percentage of raw syrup compared to not using them (Table 3). Researchers reported that under low acid conditions, the structure of sucrose in extracted syrup is broken and converted into invert sugars (glucose + fructose). Increasing the concentration of invert sugars reduces the quality of syrup because invert sugars are converted into acidic compounds (formic, acetic and lactic) and colored substances and have an adverse effect on the sugar extraction process. Another factor affecting the purity of raw syrup is zinc. The presence of zinc in the auxin hormone causes vegetative growth, branching, photosynthesis and the production of more assimilates, and it seems that the produced assimilates are used for the production of aerial biomass or the increase of the volume of the produced roots, therefore, it did not affect the purity of the raw syrup. Harvey and Dutton (Harvey, and Dutton, 2001) reported that the correlation of molasses sugar with nitrogen, sodium and potassium elements is positive and negative with syrup purity, so with the increase of these elements, molasses sugar increases and syrup purity decreases.

Harmful nitrogen impurity

Examining the variance analysis table of experimental data showed that the amount of harmful nitrogen impurity under the influence of iron, zinc and boron was placed at the probability level of 1% and 5%, respectively (Table 2). Among the levels of iron used, the highest amount of harmful nitrogen impurity is 1.44 tons per hectare related to the consumption of 75 kg per hectare of iron sulfate, and the lowest is related to the non-use of iron sulfate with an average of 0.961 tons per hectare (Table 3). In terms of consumption of zinc levels, the highest amount of harmful nitrogen impurity with an average of 1.32 tons per hectare was obtained in the treatment of no consumption of zinc sulfate (Table 3). In terms of using boric acid levels, the highest amount of harmful nitrogen impurity was obtained with an average of 1.39 tons per hectare in the first level without using boric acid. Examining the mutual effects of the factors also showed that there is a significant interaction between iron and zinc at the probability level of 5% (Table 2). Comparison of the average effect of iron and zinc showed that the highest level of harmful nitrogen impurity with an average of 1.61 tons per hectare was with the consumption of 150 kg of iron sulfate per hectare and no zinc consumption.

Alkality

Variance analysis of experimental data showed that the main effect of iron on alkalinity was significant (Table 2). The comparison of the average traits also showed that among the levels of iron used, the highest amount of alkalinity with an average of 13.6% is related to the consumption of 150 kg/ha of iron sulfate (Table 3). Examining the mutual effects of two factors also showed that there is a significant mutual effect between zinc and boron (Table 2). The average comparison between the levels of zinc and boron showed that the highest percentage of alkalinity was obtained with 14.8%, corresponding to the consumption of 100 kg per hectare of zinc and no consumption of boron. Comparison of the average interaction effect of iron, zinc and boron showed that the highest alkalinity level with an average of 15.2% is related to the consumption of 150 kg of iron and the consumption of 100 kg per hectare of zinc sulfate and the consumption of 20 kg of boric acid. Comparing the average interaction effect of zinc and boron also showed that the highest level of alkalinity was obtained with an average of 13.8% related to the consumption of 100 kg per hectare of zinc sulfate and no consumption of boric acid. Examining three-way interaction effects showed that the interaction effect of iron, zinc and boron on alkalinity level was significant (Table 2). Researchers reported that in low acid conditions, the structure of sucrose in extracted syrup is broken and converted into invert sugars (glucose+fructose) (Seyedahmadi, 2003). The comparison of the average interaction effect of iron, zinc and boron in this experiment showed that the highest alkalinity with an average of 15.6% per hectare is related to the consumption of 150 kg of iron and the consumption of 100 kg per hectare of zinc sulfate and the consumption of 20 kg of boric acid (Figure 2). Basati and colleagues (Basati *et al*., 1994) also found that 66% of pure sugar changes were caused by the alkalizing effects of sodium, potassium and nitrogen. The availability of low-use elements such as iron, zinc, and boron leads to an increase in the quantitative and qualitative yield in sugar beet, so the use of these elements is beneficial in reducing nitrogen (Artyszak *et al*., 2014).

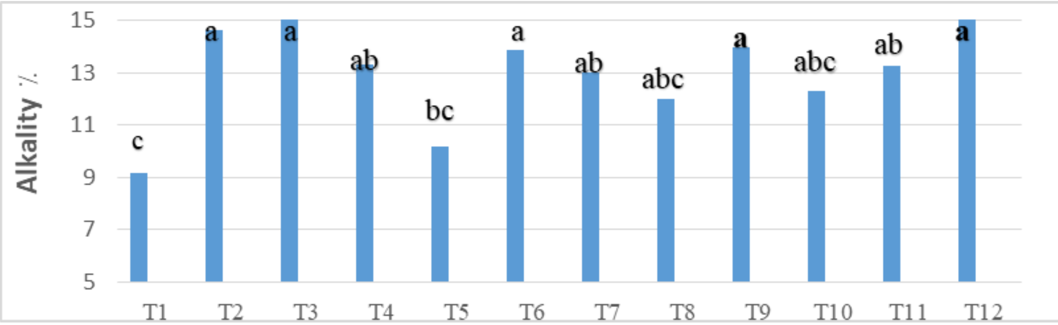

Figure 2: The effect of Fe and Zn on alkality content

T1- control T2 - 20 kg/ha boron T3 - 100 kg/ha zinc T4 - 100 kg/ha zinc and 20 kg/ha boron T5 - 75 kg/ha iron T6 - 75 kg/ha iron and 20 kg boron T7 - 75 kg/ha of iron and 100 kg of zinc T8- 75 kg/ha of iron and 100 kg/ha of zinc and 20 kg/ha of boron T9- 150 kg/ha of iron T10- 150 kg/ha of iron and 20 kg/ha of boron T11- 150 kg/ha of iron and 100 kg/ha of zinc T12- consumption of 150 kg of iron and consumption of 100 kg of zinc and consumption of 20 kg of boron

Molasses sugar content

According to the analysis of variance, the main effect of iron sulfate, zinc sulfate, and boric acid on the amount of sugar in molasses was not significant, but the interaction effect of iron, zinc, and boron on this trait was significant (Table 2). Comparison of the average interaction effect of iron, zinc and boron showed that the highest amount of sugar in molasses with an average of 3.92 tons per hectare was related to the consumption of 150 kg per hectare of iron sulfate and no consumption of zinc sulfate and boric acid (Figure 1). The real quality of beet sugar is the percentage of pure (extractable) sugar, for which it is necessary to measure the percentage of gross (total) sugar and the amount of molasses sugar. Therefore, increasing the quality of the sugar beet product is done by increasing the percentage of sugar and reducing non-sugar substances, especially nitrogen, sodium and potassium; Because the increase of these impurities by preventing the crystallization of sucrose reduces the ability to extract sugar and increases the amount of molasses produced (Honarvar *et al*., 2012).

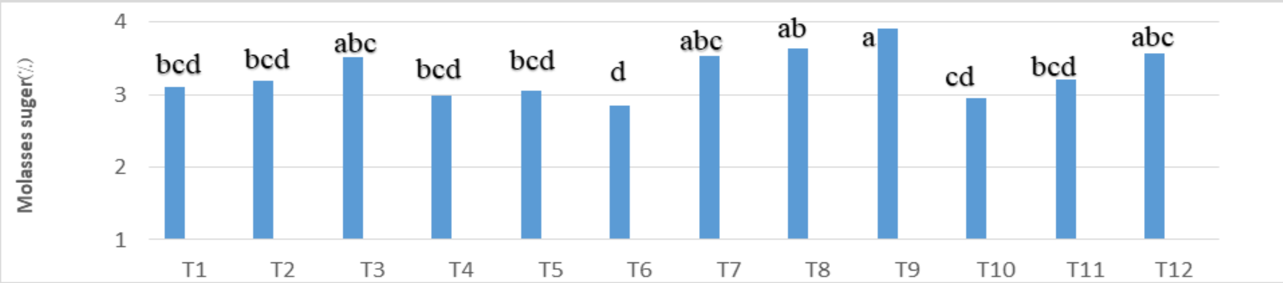

Figure 1: The effect of Fe, Zn and B on molasses sugar content

T1- control T2 - 20 kg/ha boron T3 - 100 kg/ha zinc T4 - 100 kg/ha zinc and 20 kg/ha boron T5 - 75 kg/ha iron T6 - 75 kg/ha iron and 20 kg boron T7 - 75 kg/ha of iron and 100 kg of zinc T8- 75 kg/ha of iron and 100 kg/ha of zinc and 20 kg/ha of boron T9- 150 kg/ha of iron T10- 150 kg/ha of iron and 20 kg/ha of boron T11- 150 kg/ha of iron and 100 kg/ha of zinc T12- consumption of 150 kg of iron and consumption of 100 kg of zinc and consumption of 20 kg of boron

CONCLUSION

According to the physical and chemical limitations of the soils of the region (high amount of clay, lime and high pH), the use of low consumption elements of iron, zinc and boron improved the quantitative and qualitative indicators. According to the results of this research, the combined use of zinc and boron led to the highest root yield of 63.4 tons per hectare, and since the use of these two elements together with boron improved quality indicators such as the purity of raw syrup, sugar yield, reduction The amount of impurity-nitrogen-was harmful, therefore, the use of low-consumption elements of iron, zinc, and boron, respectively, 150, 100, and 20 kg per hectare is recommended for the conditions similar to the implementation of this research.

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