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INCREASING CUCUMBER TOLERANCE OF DROUGHT UNDER CLIMATIC CHANGES USING COBALT APPLICATION

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Abstract

Cucumber has been classified a sensitive to water stress. A field experiment was carried out at Research and Production Station, National Research Centre, El-Noubaria Site, Beheira Governorate, Delta Egypt under different irrigated water levels (100%, 80%, and 60%). Seedlings of cucumber (at the third truly leaf) were irrigated once with 10.0, 12.5, 15.0, 17.5 and 20.0 ppm cobalt beside control. All required agriculture management for plant growth and production were carried out as a recommended by Ministry of Agriculture.
The obtained results could summarized as follows:-

- All cobalt treatments significantly increase the studied growth and yield parameters as well as nutritional status in cucumber fruits under different irrigated water levels (100%, 80%, and 60%).
- Cobalt at 15 ppm resulted the greatest values.
- With cobalt at 15 ppm, fruits yield of cucumber plants which grown under 80% water (6 ton/fed) significantly increase with those which grown under 100% without cobalt 4.493 ton/ feddan.
- Cobalt treatments significantly increased leaves water potential and reduced transpiration rate as well as plants water consumption.
- Cobalt levels significantly increase. Abscisic acid content which help plants to tolerate drought stress.
- Cobalt increase water use efficiency and save 20% from irrigated water.

***Keywords*:** Cucumber, cobalt, drought.

Introduction

Climate change impacts on water availability, crop yield, crop water productivity and food security. Many climate models have been developed to predict climate change impacts with higher spatial resolution climate models being helpful to provide more accurate predictions for future climate scenarios. Climate change impacts on crop yield are often integrated with its effects on water productivity and soil salinity. Climate variability has a direct, often adverse, influence on the quantity and quality of agricultural production.

Climatic changes could be summarized in the increase in temperature, global warming, the decrease of waters, increase in soil salinity floods and the change in the amount of rainfall, dryness, the increase in atmosphere humidity, the increase in ozone concentration, the pollution resulting from burning fuel and excessive in the use of mineral fertilizers.

Water stress occurs to water deficit, caused by high soil salinity or drought. In case of high salinity, water exists in the soil but plants cannot uptake it, which is called physiological drought (Chares *et al.,* 2003).

Therefore, one must put in mind that cobalt is classified as a heavy metal only in its name since heavy metals are metals that heavy a specific density higher than 5 gm/cm^3, therefore cobalt is classified as a heavy metal since its specific density is 8.9 gm/ cm^3, However, the behavior of this metal "cobalt" differ completely than the other heavy metals that possesses healthy hazards because: cobalt is the main atom in the construction of vitamin B12. Moreover B12 is necessary in the formation of red blood cells, and bones as well as mussels.

Cobalt is considered a border element for plant nutrition. It is proved to be beneficial for higher plants such as tomato, cucumber and olive in spite of the absence of evidence for direct role in their metabolism. Lisnik and Toma (2003) found that cobalt have a favorable effect in both tomato and cucumber plants dry weight, leaf number, leaf area as well as fruit yield. Nadia Gad (2005) found that the addition of 7.5 ppm cobalt had significant promotive effect on tomato growth, yield and fruit quality.

Ibrahim *et al.* (1989) indicated that application of cobalt in growth media significantly decreased stomatal aperture, leaf angle, leaf water content, leaf water potential and transpiration rate but increased water use efficiency. Duan and Auge (1992) showed that Abscisic acid is an energy inhibitor which resulted in inhibition of potassium translocation to the guard cells and subsequently stomata closure. Angelov *et al.* (1993) pointed out that the cobalt increased water content in pea plants, the rates of both photosynthesis and transpiration processes being decreased but stomatal resistance increased. Wenzel *et al.* (1995) found that the cobalt excess (400µM) in solution culture, reduced water consumption in *Phaseolus vulgaris* plants but decreased the rates of photosynthesis, transpiration, proline content and stomatal resistance were increased.

Schautmann and Wenzel (2002) studied the effect of cobalt on *Phaseolus vulgaris* under water stress condition such as drought, water logging and salinity and found that cobalt increased both Abscisic acid and ethylene hormones which are known to enhance plant resistance, promote old leaves abscission and reduce plant water losses.

Egrove (2000) found that soil application of cobalt (3mg/ kg dry soil) increased leaf water content and decreased water deficit during daytime in tomato and potato leaves. This application also increased water absorption capacity and the content of strongly bound H_2O in the leaves. Cobalt increased cytoplasmic pressure and leaf resistance to dehydration and decreased the wilting coefficient of the plants. Nadia Gad and Atta Aly (2006) reported that, high cobalt (over 18ppm) inhibited ethylene production on both tomato and cucumber plants. This was true in spite of the vital role of ethylene and Abscisic acid at low cobalt concentration in adjusting plants water valance and consequently plant growth. Nadia Gad *et al.* (2018) found that all cobalt treatments significantly increase bean growth and yield parameters as well as minerals composition of pods under different regime levels (100, 80 and 60%) compared with untreated plants. With cobalt at 12 ppm, green pods of bean plants which grown under 80% irrigated water 7.667 ton/fed is no significant with those which grown under 100% one. Cobalt increase water use efficiency and save 20% from irrigation water.

Material and Methods

1. Soil analysis

Soil samples were taken from both Tagg El-Ezz Station, Agriculture Research Centre, Dakahlya Governorat, and Research and production Station, Nobaria, Behera Governorate, Delta Egypt. Such samples were air dried and then prepared for analyses using conventional techniques.

Physical analysis

Particle size distribution, saturation percentage curve, moisture characteristics curve, bulk density, hydraulic conductivity, total porosity and texture class were determined according to Blackmore (1972).

Chemical analysis

Electrical conductivity (ds/m^{-1}), pH in soil- water suspension (1:2.5), organic matter content (%), $CaCO_3$ (%), cation exchange capacity, Exchangeable sodium (%), cations and anions in meq/liter (in soil paste), macro and micronutrients were determined according to Black *et al.* (1982).

Cobalt analysis

Total cobalt were determined in Aqua regain extract (Cottanie, 1982). The water soluble cobalt as well as available cobalt (DTPA extractable) was assayed according to Black *et al.* (1982). Determination of cobalt was carried out using Atomic Absorption Spectrophotometer, Varian AA-20.

Table 1 : Physical and chemical analysis of the experimental soils in Nobaris Station.

<table>
<tr><td rowspan="3">Physical</td><td colspan="3">Particle size distribution (%)</td><td colspan="2">Soil texture class</td><td colspan="2">Water saturation</td><td colspan="2">Field capacity</td><td colspan="2">Welting point</td><td colspan="2">Available water</td></tr>
<tr><td>Sand</td><td>Silt</td><td>Clay</td><td colspan="2" rowspan="2">Sandy loam</td><td colspan="8">%</td></tr>
<tr><td>82.6</td><td>14.6</td><td>2.8</td><td colspan="2">32.0</td><td colspan="2">14.4</td><td colspan="2">3.9</td><td colspan="2">10.5</td></tr>
<tr><td rowspan="3">Chemical</td><td rowspan="2">pH[a]</td><td rowspan="2">EC[b]</td><td colspan="6">Soluble cations (meq/l)</td><td colspan="5">Soluble anions (meq/L)</td></tr>
<tr><td colspan="2">Ca^{++}</td><td colspan="2">Mg^{++}</td><td>K^{+}</td><td>Na^{+}</td><td>HCO_3^-</td><td colspan="2">CO_3</td><td>Cl^{-}</td><td>$SO_4^=$</td></tr>
<tr><td>8.0</td><td>1.0</td><td colspan="2">9.0</td><td colspan="2">1.4</td><td>0.268</td><td>3.26</td><td>-</td><td colspan="2">1.18</td><td>0.60</td><td>12.15</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">Available</td><td colspan="5">Available micronutrients</td><td colspan="3">Cobalt (ppm)</td><td rowspan="2">$CaCO_3$</td><td rowspan="2">OM[c]</td></tr>
<tr><td colspan="4">(mg/100g)</td><td colspan="5">(ppm)</td><td>Soluble</td><td>Available</td><td>Total</td></tr>
<tr><td colspan="2">N</td><td>P</td><td>K</td><td colspan="2">Fe</td><td>Mn</td><td>Zn</td><td>Cu</td><td rowspan="2">0.39</td><td rowspan="2">1.78</td><td rowspan="2">9.68</td><td colspan="2">%</td></tr>
<tr><td colspan="2">15.2</td><td>13.0</td><td>21.2</td><td colspan="2">10.7</td><td>4.47</td><td>3.62</td><td>5.22</td><td>3.17</td><td>0.19</td></tr>
</table>

a Soil pH was measured in 1 : 2.5 soil-water suspension.
b EC was measured as dSm^{-1}in soil paste.
c organic matter.

Experimental work

Two field experiments carried out at Research and Production Station of NRC Farm, Nubaria, Elbeheara governorate to investigate the effect of two factors: Three water rates from water requirement (100, 80 and 60 %); Five Cobalt rates (5.0, 7.5, 10.0, 12.5 and 15.0 ppm cobalt beside control) within four replicates on vegetable crops production yield of (tomato, potato).

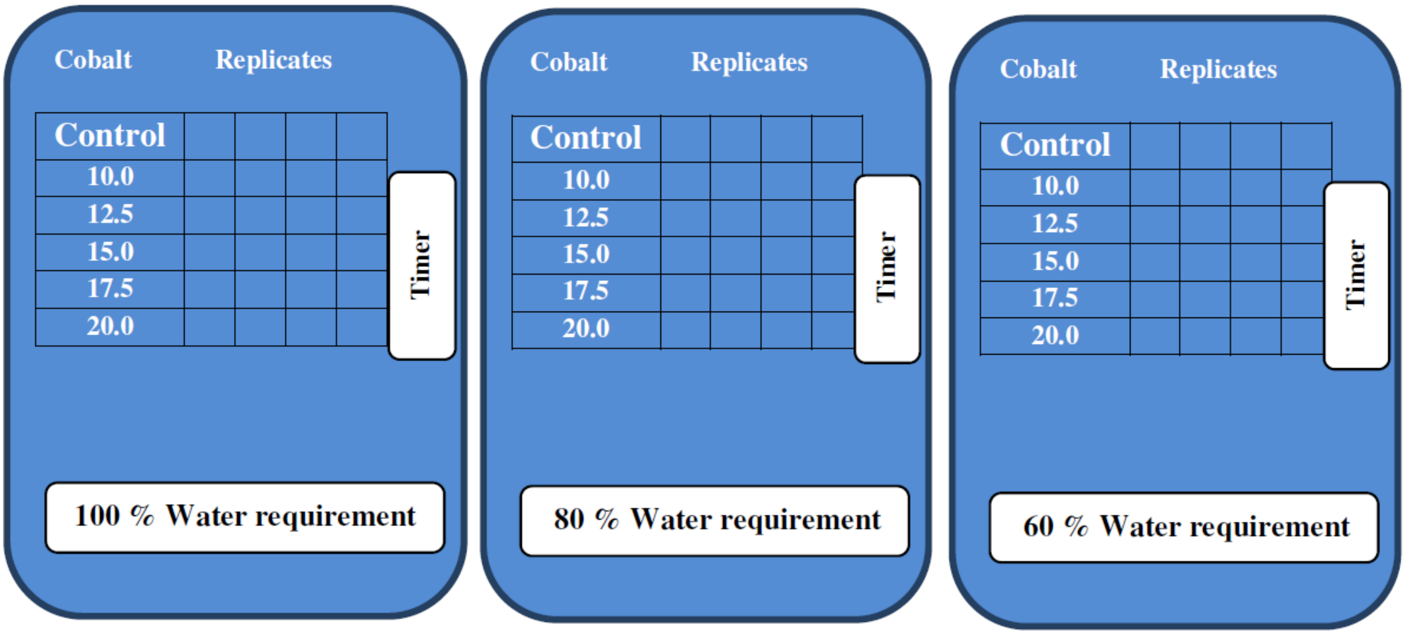

Fig. 3 : Layout of field experiments at NRC Farm, Nubaria, Elbeheara governorate.

Irrigation system components:

Control head within water pump, automatic control unit and timers, filters unit and control valves

PVC Pipes: Main lines 6 inch diameter, submain lines 63 mm diameter, and lateral lines 16mm diameters.

Drippers: GR dripper has been used.

Ground water is the source of irrigation and the values of EC, pH and SAR were 0.36 dSm^{-1}, 7.3 and 1.14 meq l^{-1}, respectively. The soil is loamy sand in texture, pH tends to be slightly alkaline (8.3) and soil EC (1:5) was 0.42 dS m^{-1} and determined according to Rebecca (2004). Soil moisture content at field capacity and permanent wilting point were 14.5 and 4.2 % on weight basis, respectively and measured after Walter and Gardener (1986).

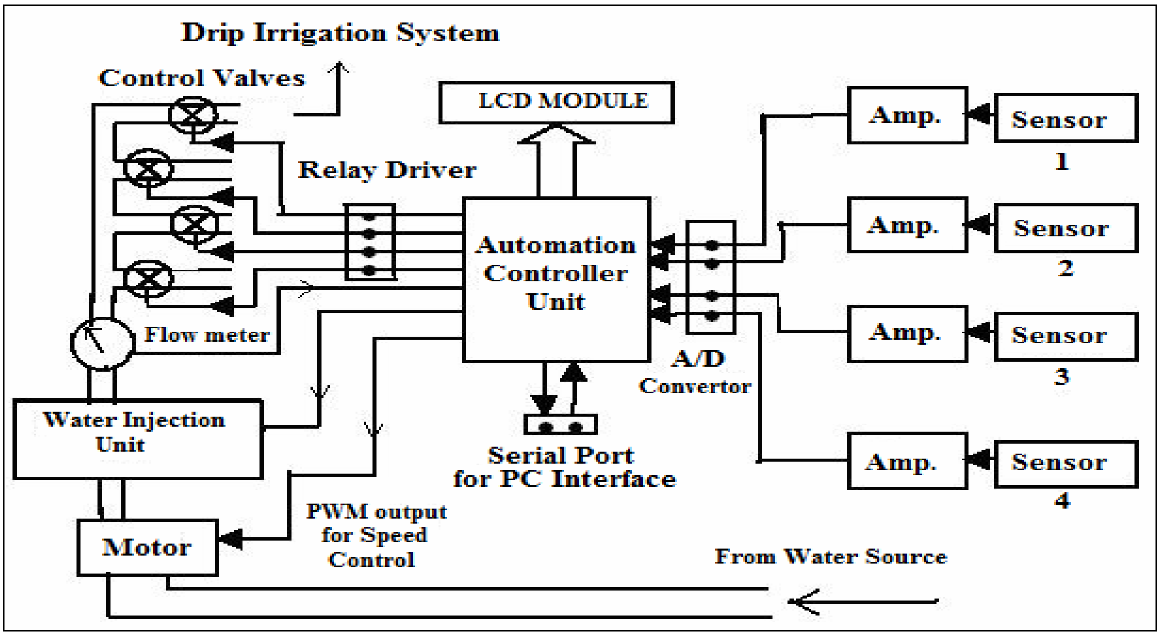

Fig. 4 : Automation controller unit

The automation controller system:

The automation controller system consists of moisture sensors, temperature sensors, signal conditioning circuit, digital to analog converter, LCD Module, relay driver, solenoid control valves, etc. The important parameters to be measured for automation of irrigation system are soil moisture and temperature. The entire field is first divided in to small sections such that each section should contain one moisture sensor and a temperature sensor. RTD like PT100 can be used as a temperature sensor while tensiometers that continuously monitor soil water status, useful for practical irrigation scheduling, and are extensively used on high-value cash crops where low water tension is desirable, can be used as the moisture sensor to detect moisture contents of soil (Fig. 4). These sensors are buried in the ground at required depth. Once the soil has reached desired moisture level the sensors send a signal to the micro controller to turn off the relays, which control the valves of drip irrigation systems used (Shinghal *et al.*, 2010 and Prathyusha and Suman, 2012).

At 6th March, seeds of cucumber (*Cucumis sativus L.*) were sown in Research and Production Station, National Research Centre, El-Noubaria Site, Beheira Governorate, Delta Egypt under different irrigated water levels (100%, 80%, and 60%). Seedlings of cucumber (at the third truly leaf) were irrigated once with 10.0, 12.5, 15.0, 17.5 and 20.0 ppm cobalt beside control. All required agriculture management for plant growth and production were carried out as a recommended by Ministry of Agriculture. The seedlings (at the third truly leaf) were irrigation with cobalt sulphate once, with the different cobalt levels (0.0, 10.0, 12.5, 15.0, 17.5 and 20.0 ppm).

Measurement of growth parameters

After 45 days growth parameters such as plant height, leaves number per plant, root length and shoot fresh and dry weight according to FAO (1980).

Measurement endogenous Abscisic acid

Fresh samples of shoot were taken for analysis of endogenous Abscisic acid according to Shindy and Smith (1975).

Measurement leaf water potential

Using leaf water meter, leaf water potential were determined in plants fresh leaves.

Measurement water consumption rate

Transpiration rate under the different studied levels (100%, 80% and 60% from available water was recorded with all cobalt concentrations.

Measurement of yield parameters

After 60-70 days from sowing, fruits were harvested and recorded according to Gabal *et al.* (1984).

Measurement of nutrition status

In cucumber fruits, macronutrients (N, P, K, Ca, Mg, Na and Cl), micronutrients (Mn, Zn, Cu and Fe) were determined according to Cottenie *et al.* (1982).

Measurement of chemical constituents

In cucumber fruits total proteins, total soluble solids, total soluble sugars and vitamin "C" as well as titrable acidity were determined according to A.O.A.C (1995).

Statistical analysis

All data were subject to statistical analysis according to procedure outlined by SAS (1996) computer program and means were compared by LSD method according to Snedecor and Cochran (1982).

Results and Discussion

Cucumber has been classified a sensitive to water stress.

Vegetative growth

Data in Table (2) show that cobalt significantly increased all cucumber growth parameter compared with untreated plants. Cobalt at 15 ppm gave the greatest values. These results are in harmony with those obtained by Lisnik and Toma (2003) who found that cobalt has a favorable effect in both tomato and cucumber dry weights, Leaf number per plants. Leaf area as well as fruits yield.

Table 2 : Effect of cobalt on cucumber plants growth parameters under different levels of irrigated water

Growth Parameters	**Plant height (cm)**			**Leaves no./plant**			**Root length (cm)**			**Shoot fresh weight (g)**			**Shoot dry weight (g)**		
Cobalt treatments (ppm)	**Irrigated water (%)**														
	100	**80**	**60**	**100**	**80**	**60**	**100**	**80**	**60**	**100**	**80**	**60**	**100**	**80**	**60**
Control	79.2	75.0	69.1	17	14	10	4.11	4.03	3.88	220	211	202	35.93	34.41	29.6
4	83.0	79.2	74.0	22	19	16	4.87	4.81	4.50	233	227	218	38.09	37.15	33.05
8	85.7	82.5	77.3	25	22	19	5.55	5.48	5.18	256	249	238	41.26	40.35	36.18
12	88.5	85.3	80.1	28	25	22	6.34	6.25	6.09	279	271	252	44.19	43.28	38.28
16	86.8	83.6	78.2	27	24	21	6.19	6.08	5.89	269	258	248	42.70	41.15	36.26
20	84.7	81.4	75.7	25	22	19	5.76	5.69	5.54	254	246	243	40.52	38.70	33.71
LSD at 5% Cobalt (A)	1.55			2.0			0.16			0.26			0.50		
Water (B)	3.30			2.8			0.60			7.55			1.18		
(A) & (B)	5.12			5.6			0.096			1.96			0.59		

Physiological content in plants

Water consumption

Data in Table (3) reveal that as increasing cobalt rates in plant media water consumption has decreased with all studied levels of irrigated water. These results are agree with those obtained by Radin (2004) who stated that cobalt increased water content in cotton leaves. The rate of transpiration have decreased but stomatal resistance increased.

Leaf water potential

Data in Table (3) show that as the concentration of cobalt in plant media increased, cucumber leaf water potential significantly decreased Cobalt is one elements which has a positive effect on higher plants to adapt water stress condition. These results are in harmony with those obtained by Duan and Auge (2001) who found that soaking soybean seeds in cobalt solution partially alleviated the effect of moisture stress on seedling growth.

Table 3 : Effect of cobalt on some physiological contents of cucumber plants under different levels of irrigated water.

Physiological contents	**Water consumption per plant (mm/season)**			**Leaf water potential per plant (-bar)**			**Abscisic acid per plant (µg per g fresh tissue)**		
Cobalt treatments(ppm)	**Irrigated water (%)**								
	100	**80**	**60**	**100**	**80**	**60**	**100**	**80**	**60**
Control	405	324	243	-14.2	-13.9	-13.1	-	0.534	0.792
10.0	375	299	219	-12.6	-12.2	-10.5	-	0.896	1.701
12.5	348	280	198	-10.7	-9.0	-7.9	-	1.320	2.420
15.0	328	262	178	-9.9	-8.1	-6.8	-	1.756	2.911
17.5	311	247	162	-8.6	-7.2	-5.6	-	2.154	3.134
20.0	285	230	147	-7.5	-6.6	-5.0	-	2.642	3.512
LSD at 5% Cobalt(A)	2.53			0.2			1.12		
Water(B)	4.81			1.1			0.82		
(A) & (B)	12.2			0.22			0.92		

Abscisic acid content

Data in Table (3) indicate that as water level decreased the content of Abscisic acid significantly increased in cucumber plants. All cobalt levels significantly increase Abscisic acid content reduce plant water consumption under the studied water regimes. These results are agree with those obtained by Anter and Nadia Gad (2001) who stated that cobalt has a promotive effect on leaf water potential and Abscisic acid stimulate stomatal closure and reduce plant water consumption under water stress condition.

Yield characteristics

Data in Table (4) show that as irrigated water level in plant media decreased, cucumber yield was decreased. All cobalt concentration has a beneficial effect on the studied yield parameters compared with control plants. Cobalt at 15 ppm gave the highest figures of yield parameters under the studied different water regimes. These results are agree with those obtained by Nadia Gad *et a.* (2012) who stated that cobalt significantly increased barley yield under different salinity levels compared with control plants.

With cobalt at 15 ppm, fruits yield of cucumber plants which grown under 80% water (6 ton/fed) significantly increase with those which grown under 100% without cobalt 4.493 ton/ feddan.

Chemical constituents of fruits

Data in Table (5) clearly indicate that the chemical constituents in cucumber fruits significantly decreased with the increasing water regime levels exception total proteins. This show the liner relationships between both Nitrogen and protein contents. All cobalt levels has a significant promotive effect on the studied chemical constituents in cucumber fruits compared with untreated plants. Cobalt at ppm gave the greatest values. These results are in harmony with those obtained by Duan and Auge (2001).

Nutritional Status

Data in Table (6&7) show that as water irrigation levels decreased the content of N, P, K, Mn, Zn and Cu in cucumber fruits decreased. All cobalt rates has a beneficial effect of these elements content. Cobalt at 15 ppm gave the greatest values. These results are agree with those obtained by Hussein (1984) who found that plant roots absorb water and soil solution containing minerals moves from the non-rhizosphere soils to words roots by mass flow under water deficit conditions.

Table 4 : Effect of cobalt on cucumber fruits yield under different levels of irrigated water

Yield parameters	Mean of fruit weight (g)			Fruits weight per plant (kg)			Fruits yield (ton per feddan)		
Cobalt treatments (ppm)	Irrigated water (%)								
	100	80	60	100	80	60	100	80	60
Control	112.3	108.6	101.8	1.797	1.520	1.120	4.493	2.800	2.630
10.0	136.9	135.0	124.1	2.464	2.430	1.862	4.960	4.175	2.855
12.5	159.7	157.6	146.3	3.354	3.152	2.487	6.385	4.680	3.818
15.0	182.8	180.9	169.2	4.387	3.980	3.722	7.878	6.000	4.175
17.5	177.3	174.8	166.1	3.901	3.496	2.990	7.753	6.890	4.575
20.0	171.2	169.0	158.4	3.424	3.398	2.534	7.650	6.615	4.335
LSD at 5% Cobalt(A)	3.17			0.36			0.96		
Water(B)	1.6			0.72			0.23		
(A) & (B)	5.7			0.259			0.221		

Table 5 : Effect of cobalt on some chemical constituents of cucumber fruits under different levels of irrigated water.

Chemical constituent	Total protein (%)			Total soluble solids (%)			Total sugar (%)			Chlorophyll content (µg per g fresh tissue)		
Cobalt treatments (ppm)	Available water (%)											
	100	80	60	100	80	60	100	80	60	100	80	60
Control	4.93	4.95	4.97	13.54	13.46	13.39	2.36	2.31	2.22	4.69	2.63	2.55
10.0	5.23	5.26	5.29	15.22	15.18	15.12	2.56	2.53	2.44	4.81	2.77	2.70
12.5	6.08	6.12	6.14	15.64	15.59	15.52	2.61	2.58	2.50	5.12	5.06	4.97
15.0	6.36	6.39	6.41	16.19	16.13	16.06	2.93	2.89	2.81	5.76	5.69	5.62
17.5	6.33	6.36	6.39	15.93	15.89	15.83	2.78	2.75	2.66	5.69	5.64	5.55
20.0	6.31	6.32	6.36	15.88	15.83	15.78	2.72	2.68	2.59	5.61	5.58	5.50
LSD at 5% Cobalt(A)	0.85			1.69			0.22			1.86		
Water(B)	0.33			0.13			0.11			0.14		
(A) & (B)	0.281			0.22			0.024			0.26		

Table 6 : Effect of cobalt on macronutrients content of cucumber fruits different levels of irrigated waterier .es .

Macronutrients (%)	N			P			K		
Cobalt treatments (ppm)	Irrigated water (%)								
	100	80	60	100	80	60	100	80	60
Control	0.789	0.792	0.795	0.861	0.863	0.866	1.122	1.126	1.128
10.0	0.836	0.842	0.846	0.883	0.8/86	0.890	1.168	1.173	1.175
12.5	0.972	0.979	0.983	0.912	0.915	0.921	1.176	1.180	1.183
15.0	1.017	1.022	1.026	1.122	1.126	1.130	1.182	1.184	1.187
17.5	1.013	1.018	1.022	1.117	1.121	1.125	1.179	1.181	1.183
20.0	1.010	1.012	1.017	1.111	1.116	1.120	1.173	1.176	1.176
LSD at 5% Cobalt(A)	0.4			0.5			0.4		
Water(B)	0.04			0.3			0.4		
(A) & (B)	0.016			0.15			0.16		

Iron content

Data in Table (7) show that reduction of Iron content in cucumber fruits, as cobalt levels in plant media were increased. According to Bisht (1991) certain antagonistic relationships between cobalt and iron.

Cobalt content

Data in Table (7) show that increasing cobalt concentration in plant media increased cobalt content in cucumber fruits. Cobalt Significantly increased (7.22 ppm) in cucumber fruits with the highest cobalt treatment (20 ppm). This level less 8 ppm. Young (1983) found that human require for his nutrition daily reach 8 ppm cobalt.

Table 7 : Effect of cobalt on micronutrients and cobalt contents of cucumber fruits under different levels of irrigated water.

Micronutrients and cobalt (ppm)	Mn			Zn			Cu			Fe			Cobalt (ppm)		
Cobalt treatments (ppm)	Irrigated water (%)														
	100	80	60	100	80	60	100	80	60	100	80	60	100	80	60
Control	29.6	30.1	31.5	32.0	32.6	33.1	26.3	26.8	27.1	141	143	146	0.86	0.89	0.92
10.0	34.5	35.2	36.4	33.5	34.1	35.0	30.0	30.7	31.3	136	139	143	2.94	2.97	2.99
12.5	35.8	37.0	38.2	34.6	35.2	36.5	31.4	31.9	32.8	132	135	138	3.65	3.70	3.73
15.0	38.0	38.3	40.5	35.9	36.4	37.8	32.7	33.0	34.2	126	130	134	4.90	4.95	4.98
17.5	36.7	36.7	38.8	35.1	35.9	36.4	31.1	31.9	33.0	121	125	129	5.52	5.58	5.61
20.0	35.9	35.1	36.4	34.0	35.1	35.9	29.2	30.5	31.7	116	119	122	7.12	7.17	7.22
LSD at 5% Cobalt(A)	1.2			1.5			3.6			0.61			0.04		
Water(B)	1.2			1.3			2.2			0.5					
(A) & (B)	1.44			1.95			7.48			0.31					

Conclusion

Cobalt is a promising element on tolerance of climatic changes in cucumber. Cobalt save 20% from irrigation water. Therefore, considerable attention should be taken concerning applying cobalt element as a fertilizers.

Cobalt help cucumber plants to resist stresses caused with drought (water deficit up to 60%). The vital role of cobalt in enhance plant senescence promote old leaves abscission and reduce plant water loss and adjusting plant water balance. The vital role of cobalt in abscisic acid biosynthesis. The vital role of abscisic is an energy inhibitor which resulted in inhibition of potassium translocation to the guard cells and subsequently stomatal closure and decrease transpiration rate. Under drought condition, cobalt significantly increase growth, fruits yield and its quality of both bean and cucumber compared with untreated plants.

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