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RESEARCH ARTICLE

Morphological and anatomical studies of grafting cucumber onto three different wild rootstocks grown under salinity in Nutrient Film Technique system.

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Abstract

This is the second in a series of papers to study the response of cucumber grafted onto three different wild rootstocks namely; *Lagnaria sicenaria*, *Luffa acutangula*, and *Cucurbita maxima* × *Cucurbita moshata* grown under Nutrient Film Technique (NFT) system with three salt concentrations (1.7, 2.9 and 4.2 dS/m) of morphological characters and anatomical structure during two successive seasons at the Station of Solar Energy Department of National Research Center, Giza, Egypt. The results of morphological and anatomical features revealed that grafting cucumber onto rootstock *Cucurbita maxima* × *Cucurbita moshata* under salt concentration 1.7 dS/m recorded higher values than their control (non-grafted) correspondent in most investigated characters. On the other hand, cucumber grafted onto rootstock *Luffa acutangula* under salt concentration of 4.2 dS/m recorded the lowest values for the same studied traits compared with the control.

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Introduction:-

Cucumber, *Cucumis sativus* L. is a member of family Cucurbitaceae and one of the most popular and widely grown vegetable crops in the world and cultivated for its fruit which is a rich source of minerals and vitamins. The fruit is eaten fresh as salads in accompaniment with other vegetables (Shuqin *et al.* 2010). It is grown in Egypt in open fields as a summer crop and under plastic houses during winter season with total yield of about 109,920 tons/year (Anonymous, 2012), and is considered moderately sensitive to salt stress.

Salinity stress is the major environmental factor limiting plant growth and productivity in arid and semiarid regions (Parida and Das, 2005). The main consequences of plant exposure to salt stress are water deficit and ion excess, which lead to several morphological and anatomical changes (Greenway and Munns, 1980). Due to natural salinity and human interferences, the arable land is continuously transforming into saline that is expected to have overwhelming global effects, resulting in up to 50% land loss by 2050 (Saha *et al*., 2010; Hasanuzzaman *et al*., 2013).

Grafting onto salt-tolerant rootstock is an effective method for increasing the salt tolerance of plants (scions). Grafting has been found to improve the salt tolerance of tomato (Santa-Cruz *et al.* 2002 and Estan *et al.* 2005), eggplant (Wei *et al*. 2007) and cantaloupe melon (Edelstein *et al.* 2005). Grafting can raise the salt tolerance of tomato by limiting transport of sodium and chloride to the shoot (Santa-Cruz *et al.* 2002and Estan *et al.* 2005).

In relation to salt tolerance, many studies have been carried out to determine the response of grafted plants to salinity (Fernández-García *et al*., 2002; Santa-Cruz *et al*., 2002; Esta˜n *et al.*, 2005; Colla *et al*., 2005 and 2006; Goreta *et al.*, 2008; Martinez-Rodriguez *et al*., 2008; He *et al*., 2009; Huang *et al*., 2009a,b; Edelstein *et al*., 2011 and Abd El-Wanis *et al*., 2012). For instance, grafting reduced the concentrations of Na+ and Cl− in the xylem (Fernández-García *et al*., 2002), as well as accumulation in leaves, of tomato (*Lycopersicon esculentum* Mill.) plants

(Santa- Cruz *et al*., 2002). However, the effect induced by the rootstock may vary with the degree of stress and duration of salt treatment (Esta˜n *et al*., 2005). Previous studies have shown that grafting can improve cucumber adaptation to salt stress (Yang *et al*. 2006).

The objective of this study is to find out the response of cucumber grafted onto three different wild rootstocks namely *Lagnaria Sicenaria*, *Luffa acutangula*, and *Cucurbita maxima* × *Cucurbita moshata* and grown under Nutrient Film Technique system with three salt concentrations (1.7, 2.9 and 4.2 dS/m). The morphological characters and anatomical structure are taken into consideration.

Materials and Methods:-

Seeds of cucumber (*Cucumis sativus* L. cv. ' Prince') and seeds of three wild rootstocks, namely *Lagnaria sicenaria*, *Luffa acutangula*, and *Cucurbita maxima* × *Cucurbita moshata* secured from Department of Vegetable Researches, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt. The field work procedures were mentioned before (Abd El-Wanis *et al*., 2012). Morphological and anatomical included the following:

1- Morphological characters

Morphological characters were recorded after 55 days from grafting (harvest time). The following characters were studied in both growing seasons:

- Stem length, cm.
- Stem diameter, at median portion (mm)
- Root length, cm
- Fresh weight of leaves (g)

In addition a random sample of 20 plants for each treatment was taken at harvest time, 55 days from grafting, to investigate the following yield characters in each of the two growing seasons:

- Number of fruits/ plant
- Fruit index

2- Anatomical studies:

A full microscopic study was carried out to investigate the anatomical structure of the different organs of cucumber. The leaf of the 5th internode represented by the middle of the leaf lamina including the midrib was taken. The stem was represented by the 5th internode counted from the plant tip. The root in addition grafting zone was investigated at the age of 55 days.

Specimens were killed and fixed for at least 48 hours in F.A.A (10 ml formalin, 5 ml glacial acetic acid, 50 ml ethyl alcohol 95%, 35ml distilled water). Plant materials were washed in 50% ethyl alcohol and dehydrated in a normal butyl alcohol series before being embedded in paraffin wax (melting point 52-54 °C). Transverse sections, 20µ thick, were cut using a rotary microtome and stained with double crystal violet/erythrosine combination, and mounted in Canada balsam (Nassar and El-Sahhar, 1998). The slides were microscopically examined and photomicrographed. Counts and measurements (µ) of the different tissues were taken.

Statistical Analysis:-

The experiment layout was a randomized complete block design with three replicates and the obtained data were statistically analyzed according to the method described by Gomez and Gomez (1984) and the combined analysis of the two seasons was calculated according to the method of Steel and Torrie (1980).

Results and Discussion:-

Morphological characters:-

The combined data of two successive seasons for morphological characters of cucumber ‘Prince’ grown under salt stress and grafted onto three different rootstock were followed up.

The investigated characters included: Stem length, stem diameter, root length and leaves fresh weight/ plant as shown in Table (1).

It is clear from values that all vegetative growth characters under salt stress 1.7 dS/m were significantly increased, being 27.23, 47.27, 21.52 and 26.25% over control plants for stem length, stem diameter, root length and leaves fresh weight/ plant; respectively. Moreover, increasing salt concentration to 4.2 dS/m caused a significant reduction in all vegetative growth characters under investigation. The maximum significant decrease below the control was recorded at 4.2 dS/m, being 1.51, 7.27, 7.63 and 1.62% less than those of control plants for stem length, stem diameter, root length and leaves fresh weight/ plant; respectively.

Regardless the salinity effect, data represented in Table (1) show that cucumber grafted onto three different rootstock had better growth behaviour than those non- grafted. Generally, the best results in this respect were obtained with rootstock *Cucurbita maxima* × *Cucurbita moshata* which recorded 10.87, 10.10, 7.14 and 33.03% over control for stem length, stem diameter, root length and leaves fresh weight/ plant; respectively. Followed by grafted cucumber onto rootstock *Lagnaria sicenaria* then *Luffa acutangula.*

The interaction between salinity concentrations and grafting onto three different rootstock showed that grafting cucumber onto rootstock *C.maxima* × *C.moshata* under salt concentration 1.7 dS/m gave the highest stem length (230.1cm), stem diameter (4.3 mm), root length (51.1 cm) and fresh weight of leaves/plant (32.4 g); followed by grafted cucumber onto rootstock *L. sicenaria* and *L. acutangula*, respectively, under the same salt concentration (1.7 dS/m).

The same trend was noted with yield characters (number of fruits/ plant and fruit index) whereas, yield characters under salt stress 1.7 dS/m increased by 14.95% over control plants for number of fruits/ plant while, fruit index recorded 3.60% (Table 1). On the other hand, increasing salt concentration to 4.2 dS/m reduced yield characters below the control by 0.74% less than control plants for number of fruits/ plant and fruit index recorded 4.12%.

It is also obvious from Table (1) that grafted cucumber onto rootstock *Cucurbita maxima* × *Cucurbita moshata* recorded the highest value (10.63%) over control for number of fruits/ plant and fruit index recorded 3.27%.

The highest values were recorded with cucumber grafted onto rootstock *C.maxima* × *C.moshata* at salt concentration 1.7 dS/m was, 52.3 followed by *L. sicenaria* (51.1) and *L. acutangula* (48) for number of fruits/ plant, respectively; under salt concentration 1.7 dS/m compared with control.

These results are in agreement with those reported by Colla *et al*. (2006) on watermelon. They found that total fruit yield and mean fruit mass were significantly affected by salinity level and grafted combination. Moreover, the fruit number was highly influenced by grafting combination but not by salinity. Relative to control plants (treated with tap water), total fruit yield of none grafted plants expose to saline solution were reduced by 19.6, 16 and 16.2% for Tex, Tex/Macis and Tex/Ercole, respectively. Also, the total fruit yield was higher by 81% in grafted than in none grafted plants, with no significant difference observed between rootstocks.

Some investigators conformed these findings on other plant species, for instance, Dorais *et al*. (2001) on tomato and Rouphael *et al*. (2006) on zucchini squash stated that total fresh yield decreased with salinity. Reduced yield under saline treatments could be attributed to NaCl increasing the osmotic potential of the solution as well as the activity of Na^+ and Cl^- ions in the root zone (Greenway and Munns (1980).

The higher yield of cucumber from grafted plants observed in this study has been similarly reported earlier by Ruiz and Romero (1999) on melon and Fernandez-Garcia *et al*. (2002) on tomato. In this concern, Edelstein *et al.* (2005) and Colla *et al*. (2006) stated that grafting did not reduce losses in melon production caused by salinity. In contrast, Romero *et al*. (1997) found that grafting mitigated the negative effect of the salinity on the yield of melon plants.

Likewise, Estan *et al.* (2005) demonstrated that grafting improved salt tolerance in tomato, as under saline conditions fruit yield of most graft combinations was significantly higher than that of the commercial hybrid Jaguar on its own rootstock – increasing up to 80% in some combinations. Moreover, the positive effect of grafting on the fruit yield was not found under favourable growth conditions but only under saline conditions.

Table 1: Morphological characters of vegetative growth and yield of cucumber grafted onto three different wild rootstocks and grown under NFT system with three salt concentrations (1.7, 2.9 and 4.2 dS/m) at 55 days old (Average of two growing seasons).

Salinity level (dS/m)		Stem length (cm)	Stem diameter (mm)	Leaves fresh weight (g)	Root length (cm)	Fruit number/plant	Fruit index
Cont.		193.62	2.75	40.65	23.50	43.25	3.76
1.7		216.35	4.05	49.40	29.67	49.72	3.60
2.9		205.67	3.12	44.67	26.55	45.12	4.09
4.2		190.70	2.55	37.55	23.12	43.57	4.12
L.S.D. (0.05%)		**0.69**	**0.04**	**0.32**	**0.20**	**0.18**	**0.03**
Rootstocks							
Control (non grafted)		194.15	2.97	24.50	37.45	43.27	4.47
Cucurbita maxima* × *Cucurbita moshata		215.27	3.27	25.95	49.82	47.87	3.27
Luffa acutangula		196.60	3.05	26.15	40.85	43.82	4.06
Lagnaria sicenaria		200.32	3.17	26.25	44.15	46.70	3.91
L.S.D. (0.05%)		**1.24**	**0.02**	**0.11**	**0.69**	**0.29**	**0.05**
Control (non grafted)	Cont.	186.3	2.6	22.2	35	41	4.6
	1.7	209	3.8	28	43.8	47.5	4.15
	2.9	198.3	3.2	27	39.1	43.3	4.43
	4.2	183	2.3	20.8	31.9	41.3	4.79
Cucurbita maxima* × *Cucurbita moshata	Cont.	207.4	2.9	22.4	49.1	45.8	3.07
	1.7	230.1	4.3	32.4	51.1	52.3	3.20
	2.9	219.4	3.2	26.7	53.1	47.2	3.35
	4.2	204.2	2.7	22.3	46	46.2	3.47
Luffa acutangula	Cont.	188.4	2.7	24	37.6	41.5	3.96
	1.7	211.1	4	27.9	49.7	48	3.77
	2.9	200.5	3	26.3	41.6	44	4.41
	4.2	186.4	2.5	26.4	34.5	41.8	4.14
Lagnaria sicenaria	Cont.	192.4	2.8	25.4	40.9	44.7	3.68
	1.7	215.2	4.1	30.4	53	51.1	3.43
	2.9	204.5	3.1	26.2	44.9	46	4.36
	4.2	189.2	2.7	23	37.8	45	4.34
L.S.D. (0.05%)		**1.38**	**0.08**	**0.40**	**0.65**	**0.35**	**0.07**

Anatomical studies:-

Differences in cucumber leaf structure due to the interaction between grafting and salt stress

Microscopical measurements of certain histological characters in transverse sections through the blade of fifth leaf at the age of 55 days (harvest time) of control plants, plants grafted onto rootstock *C.maxima × C.moshata* under salt concentration 1.7 dS/m and of those grafted onto rootstock *luffa acutangula* under salt concentration 4.2 dS/m are presented in Table (2). Also, microphotographs depict these treatments are shown in Figure (1).

It is obvious from Table (2) and Figure (1) that grafted cucumber onto rootstock *C.maxima* × *C.moshata* and under salt concentration of 1.7 dS/m increased upper and lower epidermis by 34.2 and 25% over control. Thickness of both midvein and lamina of cucumber leaf of grafted cucumber onto rootstock *C.maxima* × *C.moshata* and under salt concentration of 1.7 dS/m increased by 8.7 and 28.5% more than those of the control; respectively. It is noted that the increase in lamina thickness was accompanied with 1.4 and 36.3% increments in thickness of palisade and spongy tissues compared with the control; respectively. Results also indicated that the thickness of xylem and phloem increased by 27.5 and 7.1% over control. Moreover, xylem vessels had wider cavities, being 11.1% more than the control. Hence the role of xylem for water and mineral absorption plus the function of phloem for storage amount of carbohydrate which reflect to this vigor of growth than other rootstocks. In the mean time mechanical tissues (upper and lower collenchyma and fiber) also increased than control by 36.3, 1.4 and 14.2%, respectively.

It is observed from Table (2) and Figure (1) that cucumber grafted onto rootstock *luffa acutangula* under salt concentration 4.2 dS/m increased thickness of upper epidermis by 33% than control, while lower epidermis decreased by 4.9 under control. On the other hands, midvein and lamina decrease by 17.3 and 3.4% less than the control; respectively. It is clear that the decreased in lamina thickness was accompanied with decrease by 5.8 and 4.5% in thickness of palisade and spongy tissues less than control; respectively. Likewise, the midvein was decreased in size due to the decreased in xylem by 20% and in phloem by 0.6% less than the control. Also, vessels decreased in diameter by 33.3% less than the control. Moreover, upper and lower collenchyma and fiber decreased less than control by 3.9, 42.6 and 14.2, respectively.

The present results are generally in agreement with those recorded by David and Nobel, 1979. They reported that raising the concentration of NaCl in hydroponic solutions resulted in greater mesophyll thickness for bean, cotton, and atriplex due to an increase in length of palisade cells as well as diameter and an increased number of spongy cell layers as well as spongy cell diameters tended to increase with salinity. Chartzoulakisa *et al*., 2002, however, reported that water stress resulted in a significant decrease of the thickness of almost all histological components of the mesophyll, as well as of the entire lamina thickness.

Table 2: Microscopical measurements (µ) of certain histological features in transverse sections through the leaf of cucumber grafted onto rootstock *Cucurbita maxima* × *Cucurbita moshata* under salinity 1.7 and cucumber grafted onto rootstock *luffa acutangula* under salt concentration of 4.2 dS/m

Histological characters	Control (non grafted)	*Cucurbita maxima* × *Cucurbita moshata*	± % to control	*Luffa acutangula*	± % to control
Upper epidermis	21.3	28.6	+34.2	28.4	+33.3
Lower epidermis	28.4	35.5	+25	27.0	- 4.9
Midvein thick	2371.4	2577.3	+8.7	1959.6	- 17.3
Lamina thick	248.5	319.5	+28.5	240.0	- 3.4
Palisade thick	78.1	79.2	+1.4	73.8	- 5.8
Spongy thick	156.2	213.0	+36.3	149.1	- 4.5
Xylem thick	284	362.1	+27.5	227.2	- 20
Phloem thick	99.4	106.5	+7.1	100	- 0.6
Vessels diameter	63.9	71	+11.1	42.6	- 33.3
Upper collenchymas thick	156.2	213	+36.3	150.0	- 3.9
Lower collenchymas thick	99.0	100.4	+1.4	56.8	- 42.6
Fiber thick	99.4	113.6	+14.2	85.2	- 14.2

Differences in cucumber stem structure due to the interaction between grafting and salt stress:-

Microscopically measurements of certain histological features in transverse sections through the fifth internode of the main stem of cucumber at the age of 55 days of control plants, plants grafted onto rootstock *Cucurbita maxima* × *Cucurbita moshata* under salt concentration 1.7 dS/m and of those grafted onto rootstock *luffa acutangula* under salt concentration 4.2 dS/m are presented in Table (3) and Figure (2).

As shown in Table (3) and Figure (2) the grafted cucumber onto rootstock *Cucurbita maxima* × *Cucurbita moshata* and under salt concentration of 1.7 dS/m increased the diameter of the main stem by 13.4% over that of the control. The thickness of cortex, fiber strands, outer and inner phloem and xylem were increased over those of the control by 33.3, 57.8, 42.8 and 3.3%; respectively. It is realized from Table (2) and Figure (1) that diameter of the main stem in cucumber grafted onto rootstock *luffa acutangula* under salt concentration 4.2 dS/m decreased by 5.4% less than control. Moreover, the thickness of cortex, outer and inner phloem and xylem were decreased by 16.6, 2.8, 28.5 and 6.6% less than control; respectively.While fiber strands thickness increased by 84.2% over control. The increase of fiber thickness caused decrease for distinguish the cell which responsible for differentiate the tissues, where vascular connection of *Cucurbita maxima* × *Cucurbita moshata* was more rapidly and appearance in connect area than other rootstocks and that lead to a successful graft earlier than other depending on the activity of cambial tissue, so these are an opposite relationship between amount of fiber and grafting success.

The present results are in accordance with those reported by Hameed *et al*.(2010) on *Cynodon dactylon*, reported that stem area, epidermis cell, phloem area, sclerenchyma and cortical thickness were increased with increasing salt concentration. Number of vascular bundles and Vascular bundle area was increased by the imposition and by further induction of salt. It was gradually decreased. Likewise, Datta and Som (1973) and Gadallah and Ramadan (1997) and Akram *et al.*, 2002, LingAn *et al*., (2002) and Reinoso *et al*., (2004) on *Prosopis strombulifera*, recorded that salinity reduced plant stem area, epidermal cell area in stem and xylem vessels

Differences in rootstock root structure due to the interaction between grafting and salt stress:-

It is clear from Table (4) and Fig. (3) that root of cucumber grafted onto *Luffa acutangula* showed that thickness of cortex was increased by 44.5% over control, whereas cucumber grafted onto *Cucurbita maxima* × *Cucurbita moshata* decrease by 8.3% less than control. On the other hand, according to vascular cylinder, a decreased in thickness was recorded in cucumber grafted onto *C.maxima* × *C.moshata* and *Luffa acutangula* by 10.8 and 46.9% less than control, respectively.

As shown in Table (4) all root structure under studies showed a secondary growth which differed in amount from each other related to activity of cambium and the stress of salt and noticed that secondary growth was more pronounced for non grafted cucumber and cucumber grafted onto *C.maxima* × *C.moshata* followed by cucumber grafted onto *Luffa acutangula*. Root diameter kept the same trend like dimension of vascular cylinder which exhibited a highest value for control followed by *C.maxima* × *C.moshata* and *Luffa acutangula* by 1441.3, 1050.8 and 717.1 µ, respectively.

Table 3: Microscopical measurements (µ) of certain histological features in transverse sections of cucumber stem grafted onto rootstocks, *Cucurbita maxima* × *Cucurbita moshata* under salt concentration 1.7 and cucumber stem grafted onto rootstocks *Luffa acutangula* under salt concentration of 4.2 dS/m

Histological characters	Control (non grafted)	*Cucurbita maxima* × *Cucurbita moshata*	± % to control	*Luffa acutangula*	± % to control
Diameter of whole stem section	3965.5	4500	+13.4	3750	-5.4
Cortex thick	150	200	+33.3	125	-16.6
Fiber thick	47.5	75	+57.8	87.5	+84.2
- **Outer phloem**	175	250	+42.8	170	-2.8
- **Xylem**	750	775	+3.3	700	-6.6
- **Inner phloem**	175	250	+42.8	125	-28.5

According to effect of salt stress on rootstocks, it is obvious that the high concentration of salinity had more effect on *Luffa acutangula* and that was clear in decrease the thickness of vascular cylinder more than non-grafted cucumber and *C.maxima* × *C.moshata*, which exhibited a large amount of thickness of xylem more than the other, which proved that both non grafted cucumber and *C.maxima* × *C.moshata* more bear than other, and that was clear for large amount and thickness of secondary xylem. The less affected root area in *C.maxima* × *C.moshata* proved the better adaptation to this root stock than other.

These results agree with Hameed *et al*. (2010) on *Cynodon dactylon*, who reported that root area decreased consistently but significantly with rise in NaCl level. Exodermis cell area showed stability in this character and was not much affected by increasing salt levels. Sclerenchyma thickness and its cell area showed an increase in both characters with increase in salt levels. Cortical thickness showed gradual increase with increase in salt levels. There was an increase in vascular region thickness at lower salt levels *i.e*., 50 and 100 mM NaCl. Phloem area showed a decreasing trend. The pith area was enhanced with increase in salt levels. De Villiers *et al*., (1995), found that as salt level increased a decrease was observed in root diameter as reported by salinity is known to stimulate suberization of the root hypodermis and endodermis (Kozlowski, 1997).

Saline tolerant species are often characterized by thick inner tangential walls of endodermis and lignified walls of cortical parenchyma (Baumeister and Merten, 1981; Walsh, 1990; Hwang and Chen, 1995; Baloch *et al.*, 1998; YuJing and Yong, 2000; YuJing *et al.*, 2000). Akram *et al.*, (2002) reported decreased cortical and pith region in wheat under salinity, though well developed parenchyma is a characteristic feature of salt tolerant species such as salt grass (Alshammary *et al.*, 2004). In bean-root vascular tissue, NaCl caused earlier and stronger lignifications, which has been suggested to be a factor that inhibits root growth and, consequently, represents an adaptation mechanism in resisting salinity-imposed stress (Cachorro *et al.*, 1993).

Simon *et al*. (2008) reported that indicators of graft incompatibility in *Uapaca kirkiana* trees include growth irregularities at the union, presence of necrotic tissues, and phenolic deposits at the union interface. Such findings confirm existence of graft union problems, although these trees were surviving in the nursery. However, phenol quantification and identification are needed to support the role of phenols in graft compatibility. For graft-incompatible partners, portions of parenchymal tissues supported the graft unions. Good compatibility in grafting can be noticed by higher number of vessels with less necrotic layer at graft union. While less incompatible of grafting could be noticed by a lower number of vessels with a large number of necrotic layer at graft union.

In essence, the results of this study indicate a high degree of graft compatibility between cucumber (scions) grafted onto *Cucurbita maxima* × *Cucurbita moshata* (rootstock). Approved by the high percentage of success, the establishment of vascular tissue connectivity observed in the histological study and the excellent growth observed 55 days (harvest time) after grafting. In additionally, there was a partial incompatibility between cucumber (scions) grafted onto *Luffa acutangula* (rootstock), indicated by low success, presence of unbroken or slightly fragmented necrotic layer and stunted growth (F.g. 4)

Table 4: Microscopical measurements (µ) of certain histological features in transverse sections of rootstocks root, cucumber grafted onto rootstocks, *Cucurbita maxima* × *Cucurbita moshata* under salt concentration 1.7 and cucumber grafted onto rootstocks *Luffa acutangula* under salt concentration of 4.2 dS/m

Histological characters	Control (non grafted)	*Cucurbita maxima* × *Cucurbita moshata*	± % to control	*Luffa acutangula*	± % to control
Cortex thick	201.4	184.6	-8.3	291.1	+44.5
Dimension of vascular cylinder	589.4	525.4	-10.8	312.4	-46.9
root diameter	1441.3	1050.8	-27.1	717.1	-50.2

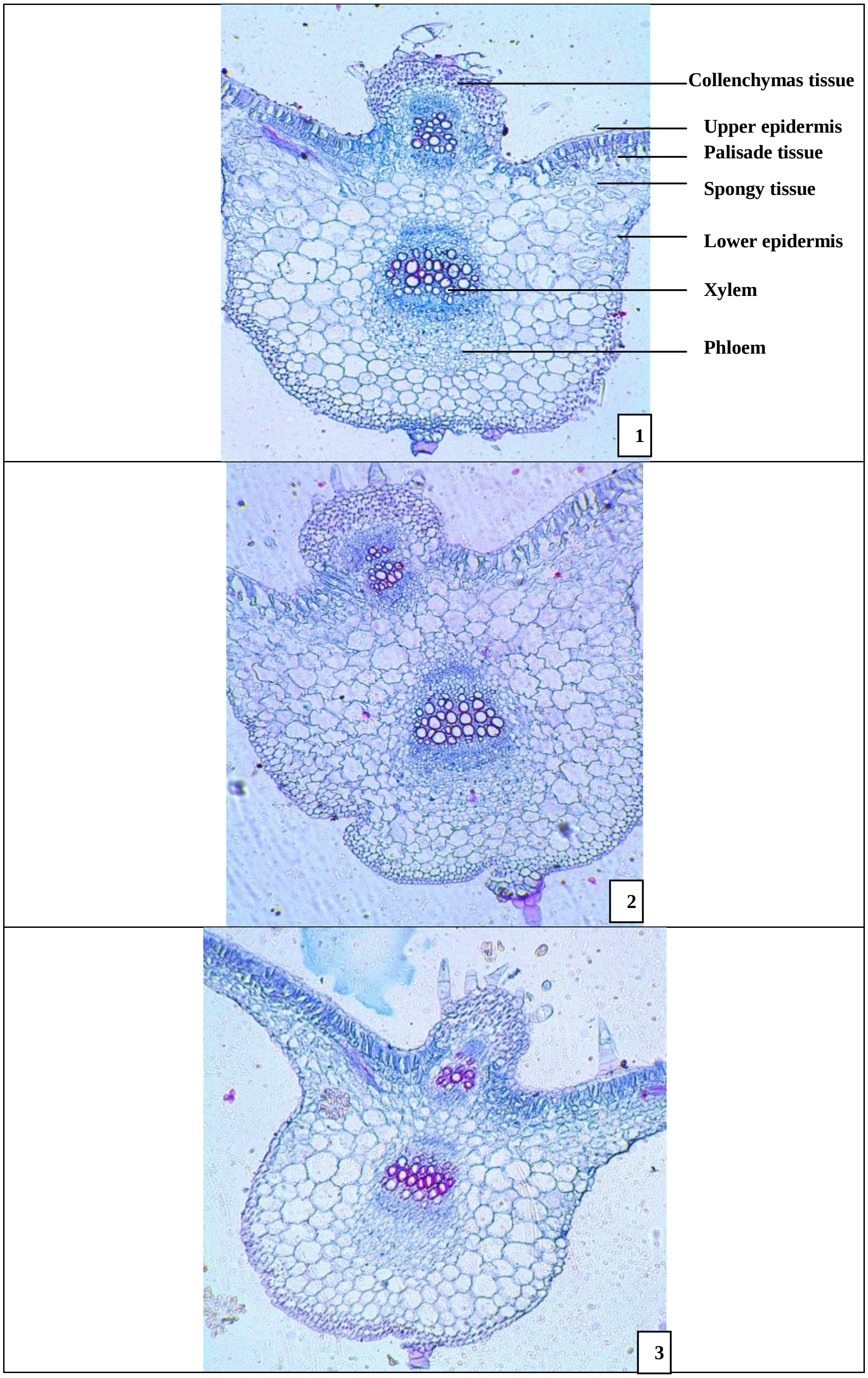

Fig. (1): Microphotographs showing transverse sections of cucumber leaf.

(1) Control (non- grafted)

(2) Cucumber grafted onto rootstock *C.maxima* × *C.moshata* under salt concentration 1.7 dS/m

(3) Cucumber grafted onto rootstock *Luffa acutangula* under salt concentration 4.2 dS/m

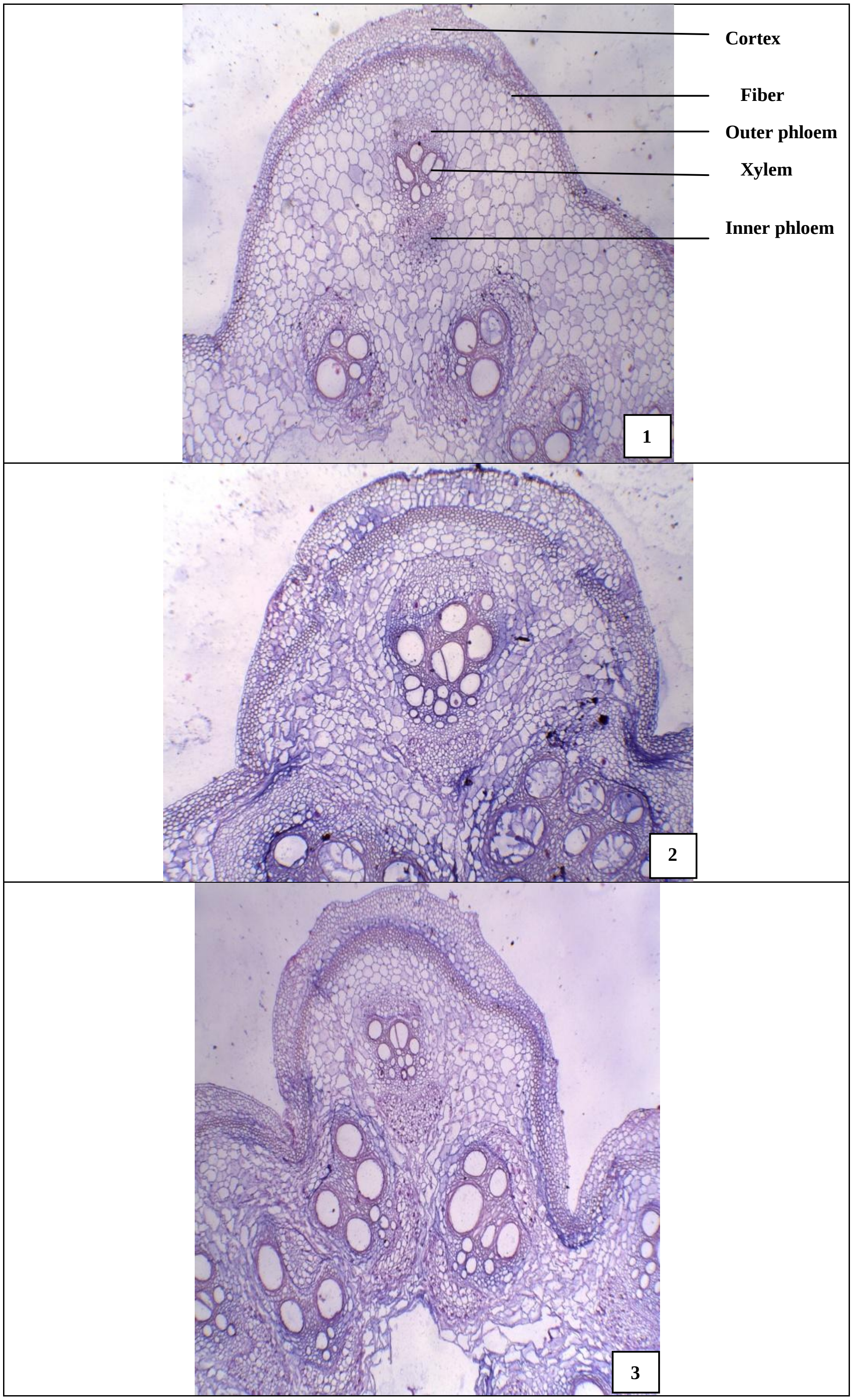

Fig. (2): Microphotographs showing transverse sections of cucumber stem.

(1) Control (non- grafted)
(2) Cucumber grafted onto rootstock *C.maxima* × *C.moshata* under salt concentration 1.7 dS/m
(3) Cucumber grafted onto rootstock *Luffa acutangula* under salt concentration 4.2 dS/m

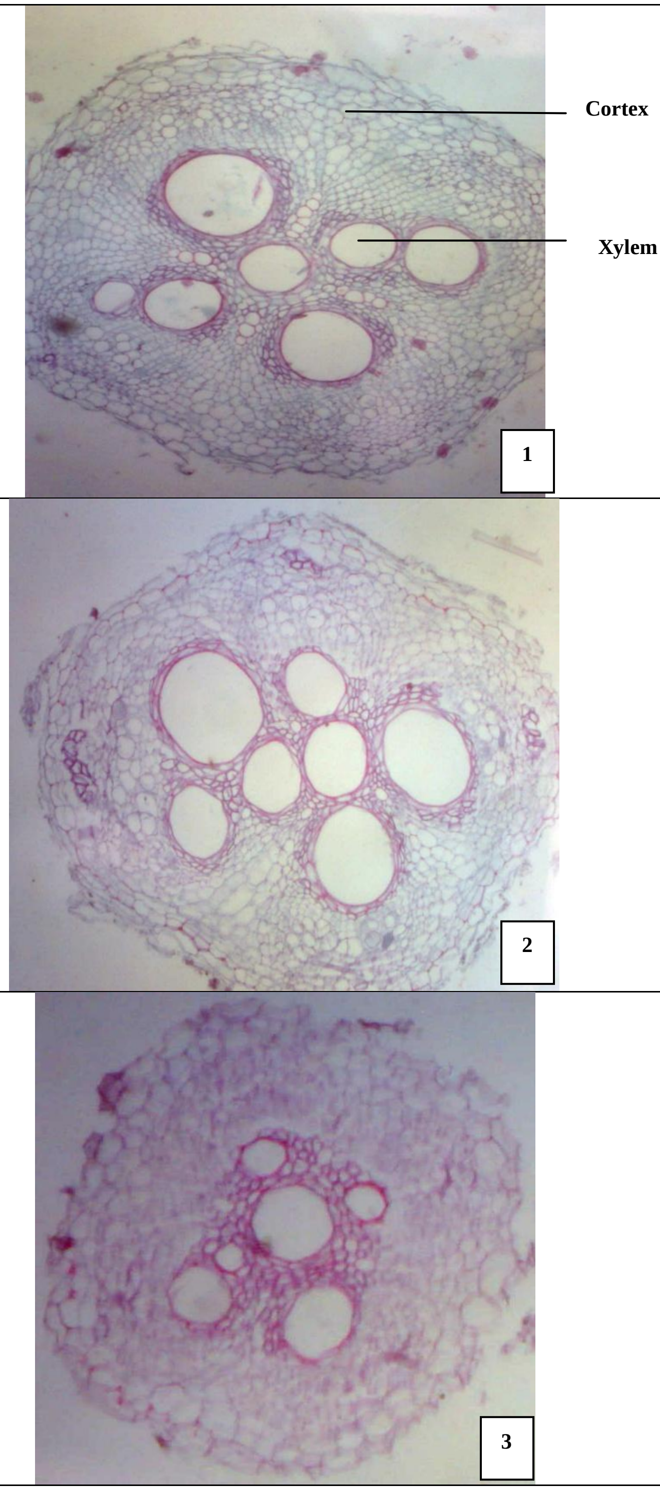

Fig (3): Microphotographs showing transverse sections of cucumber and rootstocks root.

(1) Control (non- grafted)

(2) Cucumber grafted onto rootstock *C.maxima* × *C.moshata* under salt concentration 1.7 dS/m

(3) Cucumber grafted onto rootstock *Luffa acutangula* under salt concentration 4.2 dS/m

Fig (4): Microphotographs showing transverse sections of grafting zone

(1) Control (non- grafted)

(2) Cucumber grafted onto rootstock *C.maxima* × *C.moshata* under salt concentration 1.7 dS/m

(3) Cucumber grafted onto rootstock *Luffa acutangula* under salt concentration 4.2 dS/m

References:-

1. **Abd El-Wanis, Mona M., M.H. Abdel-Baky and S.R. Salman (2012):** Effect of grafting and salt stress on the growth, yield and quality of cucumber grown in NFT system. Journal of Applied Sciences Research, 8(10): 5059-5067
2. **Akram, M., Akhtar, S., Javed, I.H., Wahid, A. and Rasul, E. (2002):** Anatomical attributes of different wheat (*Triticum aestivum*) accessions/varieties to NaCl salinity. Int. J. Agri. Biol., 4: 166-168.
3. **Alshammary, S.F., Qian, Y.L. and Wallner, S.J. (2004):** Growth response of four turf grass species to salinity. Agric. Water Manag., 66: 97-111.
4. **Anonymous. (2012)**: Economic and statistics, Ministry of Agriculture and land Reclamation Manual Report, Dept Agric, Egypt.
5. **Baloch, A.H., Gates, P.J. and Baloch, V. (1998):** Anatomical changes brought about by salinity in stem, leaf and root of *Arabidopsis thaliana* (L.) Heynh (thale cress). Sarhad J. Agric., 14: 131-142.
6. **Baumeister, W. and Merten, A. (1981):** Effect of NaCl concentration in the culture solution on the growth and root anatomy of two subspecies of *Festuca rubra* L. Angewandte Botanik, 55: 401-408.
7. **Cachorro, P., Ortiz, A. and CerdaÂ, A., 1993**. Growth, water relations and solute composition of *Phaseolus vulgaris* L. under saline conditions. Plant Sci. 95, 23±29.
8. **Colla, G., Rouphael, Y., Cardarelli, M. and Rea, E. (2006):** Effect of salinity on yield, fruit quality, leaf gas exchange, and mineral composition of grafted watermelon plants. Hort Science 41:622–627.
9. **Colla, G., Fanasca, S., Cardarelli, M., Rouphael, Y., Saccardo, F., Graifenberg, A. and Curadi, M. (2005):** Evaluation of salt tolerance in rootstocks of *Cucurbitaceae*. Acta Horticulturae 697: International Symposium on Soilless Culture and Hydroponics.
10. **Chartzoulakisa, K., Patakasb, A., Kofidisc, G., Bosabalidisc, A. and Nastoub, A. (2002)**. Water stress affects leaf anatomy, gas exchange, water relations and growth of two avocado cultivars. Sci Hortic.95:39–50.
11. **Datta, S.K. and J. Som. 1973.** Note on the effect of salinity on the structural changes in the stem of rice varieties. Ind. J. Agric. *Sci*., 43: 614-617.
12. **David, J.L. and Nobel, P.S. (1979):** Salinity Effects on Leaf Anatomy. Plant Physiol. 63, 700-703.
13. **De Villiers, A.J., Von Teichman, I., Van Rooyen, M.W. and Theron, G.K. (1995):** Salinity-induced changes in anatomy, stomatal counts and photosynthetic rate of *Atriplex semibaccata* R. Br. S. Afr. J. Bot., 62: 270-276.
14. **Dorais, M., Papadopoulos, A.P. and Gosselin, A. (2001):** Influence of electric conductivity management on greenhouse tomato yield and fruit quality. Agronomie 21:367-383.
15. **Edelstein, M., Ben-Hur, M., Cohen, R., Burger, Y. and Ravina, I. (2005):** Boron and salinity effects on grafted and non-grafted melon plants. Plant Soil 269, 273–284.
16. **Edelstein, M., Plaut, Z. and Ben-Hur, M. (2011):** Sodium and chloride exclusion and retention by non-grafted and grafted melon and Cucurbita plants. J. Expt. Bot. 62:177–184.
17. **Estan, M.T., Martinez-Rodriguez, M.M., Perez-Alfocea, F., Flowers, T.J. and Bolarin, M.C. (2005):** Grafting raises the salt tolerance of tomato through limiting the transport of sodium and chloride to the shoot. J. Exp. Bot. 56, 703–712.
18. **Fernandez-Garcia, N., Martinez, V., Cerd´a, A. and Carvajal, M. (2002)**. Water and nutrient uptake of grafted tomato plants grown under saline conditions. J. Plant Physiol. 159, 899–905.
19. **Gadallah, M.A.A. and Ramadan, T. (1997**): Effects of zinc and salinity on growth and anatomical structure of *Carthamus tinctorius* L. Biol. Plant., 39: 411-418.
20. **Gomez, K.A. and Gomez, A.A. (1984):** Statistical procedures for Agriculture Research. 2 Willey Inter, Science, Publ., 357-423.
21. **Goreta, S., Bucevic-Popovic, V., Selak, G.V., Pavel-Vrancıc, M. and Perica, S. (2008):** Vegetative growth, superoxide dismutase activity and ion concentration of salt-stressed watermelon as influenced by rootstock. J Agri Sci 146: 695–704.
22. **Greenway, H. and Munns, R. (1980)**. Mechanisms of salt tolerance in nonhalophytes. Annual Review of Plant Physiology 31, 149–190.
23. **Hameed, M., Ashraf, M., Naz, N. and Al-Qurainy, F. (2010):** Anatomical adaptations of *Cynodon dactylon* (L.) Pers., from the Salt Range Pakistan, to salinity stress. I. root and stem anatomy.
24. **Hasanuzzaman, M., Nathan, K. and Fujita, M. (2013):** Plant response to salt stress and role of exogenous protectants to mitigate salt-induced damages. In: Ahmad, P., Azooz, M.M., Prasad, M.N.V. (Eds.), Ecophysiology and responses of plants under salt stress. Springer, New York, pp. 25-87.
25. **Hwang, Y.H. and Chen, S.C. (1995):** Anatomical responses in *Kandelia candel* (L.) Druce seedlings growing in the presence of different concentrations of NaCl. Bot. Bull. Acad. Sin., 36: 181-188.

26. **He, Y., Zhu, Z.J., Yang, J., Ni, X.L. and Zhu, B. (2009):** Grafting increases the salt tolerance of tomato by improvement of photosynthesis and enhancement of antioxidant enzymes activity. Environ. Exp. Bot. 66, 270–278.
27. **Huang, Y., Bie, Z., He, S., Hua, B., Zhen, A. and Liu, Z. (2009b):** Improving cucumber tolerance to major nutrients induced salinity by grafting onto *Cucurbita ficifolia*. Environ. Exp. Bot. 69, 32–38.
28. **Huang, Y., Tang, R., Cao, Q. and Bie, Z. (2009a):** Improving the fruit yield and quality of cucumber by grafting onto the salt tolerant rootstock under NaCl stress. Sci. Hortic. 122, 26–31.
29. **Kozlowski, T.T. (1997):** Responses of Woody Plants to Flooding and Salinity. Tree Physiology Monograph No. 1, Heron Publishing, Victoria, Canada. Page: 1-29.
30. **LingAn, K., GuoHan, S., LiPing, L., RongZong, C. and FaZeng, L. (2002):** A comparative anatomical study on morphology and structure of *Trifolium vulgare* Nees in different habitats. J. Shandong Agric. Univ., 33: 331-337.
31. **Martinez-Rodriguez,M.M., Estan, M.T., Moyano, E., Garcia-Abellan, J.O., Flores, F.B., Campos, J.F., Al-Azzawi, M.J., Flowers, T.J. and Bolarin, M.C. (2008):** The effectiveness of grafting to improve salt tolerance in tomato when an 'excluder' genotype is used as scion. Environ. Exp. Bot. 63:392–401.
32. **Nassar, M.A. and El-Sahhar, K.F. (1998):** Plant microtechnique. Academic Bookshop, Egypt. 224 pp. (In Arabic).
33. **Parida, A.K. and Das, A.B. (2005):** Salt tolerance and salinity effect on plants: A review. Ecotoxicol. Environ. Safety 60:324-349.
34. **Reinoso, H., Sosa, L., Ramírez, L. and Luna, V. (2004):** Salt-induced changes in the vegetative anatomy of *Prosopis strombulifera* (Leguminosae). Can. J. Bot., 82: 618-628.
35. **Romero, L., Belakbir, A., Ragala, L. and Ruiz, M. (1997):** Response of plant yield and leaf pigments to saline con-ditions: Effectiveness of different rootstocks in melon plants (*Cucumis melo* L.). *Soil Science and Plant Nutri-tion*, 43, 855-862.
36. **Rouphael, Y., Cardarelli, M., Rea, E., Battistelli, A. and Colla, G. (2006):** Comparison of the subirrigation and drip-irrigation systems for greenhouse zucchini squash production using saline and non-saline nutrient solutions. Agr. Water Mgt. 82:99–117.
37. **Ruiz, J.M. and Romero, L. (1999)**. Nitrogen efficiency and metabolism in grafted melon plants. Sci. Hort. 81:113–123.
38. **Saha, P., Chatterjee, P. and Biswas, A.K. (2010):** NaCl pretreatment alleviates salt stress by enhancement of antioxidant defense and osmolyte accumulation in mungbean (*Vigna radiata* L. Wilczek). Indian J. Exp. Biol. 48:593-600.
39. **Santa-Cruz, A., Martı´nez-Rodrı´guez, M.M., Perez-Alfocea, F., Romero-Aranda, R. and Bolarin, M.C. (2002):** The rootstock effect on the tomato salinity response depends on the shoot genotype. Plant Sci. 162:825–831.
40. **Shuqin Wan, YaohuKanga, DanWangb and Shi-pingLiua (2010):** Effect of saline water on cucumber(*Cucumis sativus* L.) yield and water use under drip irrigation in North China. Agricultural Water Management.
41. **Simon A. Mng'omba, Elsa S. du Toit and Festus K. Akinnifesi (2008):** The relationship between graft incompatibility and phenols in *Uapaca kirkiana* Mu¨ ell Arg. Scientia Horticulturae 117, 212–218
42. **Steel, R.G.D. and Torrie, J.H. (1980):** Principles and Procedures of Statistics. Mc Crow-Hill Book Co., Inc., New York, Toronto, London.
43. **Walsh, G.E. (1990):** Anatomy of the seed and seedling of *Spartina alterniflora* Lois. (Poaceae). Aquatic Bot., 38: 177-193.
44. **Wei G.P., Zhu Y.L., Liu Z.L., Yang L.F. and Zhang G.W. (2007):** Growth and ionic distribution of grafted eggplant seedlings with NaCl stress. Acta Bot. Boreal Occident Sin. 27:1172-1178.
45. **Yang, L.F., Zhu, Y.L., Hu, C.M., Liu, Z.L. and Zhang, G.W. (2006):** Effects of NaCl stress on the contents of the substances regulating membrane lipid oxidation and osmosis and photosynthetic characteristics of grafted cucumber. Acta Botanica Boreali-Occidentalia Sinica. Science Press, Beijing, China, 26(6): 1195-1200.
46. **Yujing, Z. and Yong, Z. (2000):** Studies on ultrastructure of *Puccinellia tenuiflora* under different salinity stress. Grassland China, 4: 30-32.
47. **Yujing, Z., Yong, Z., Zizhi, H. and Shunguo, Y. (2000):** Studies on microscopic structure of *Puccinellia tenuiflora* stem under salinity stress. Grassland China, 5: 6-9.