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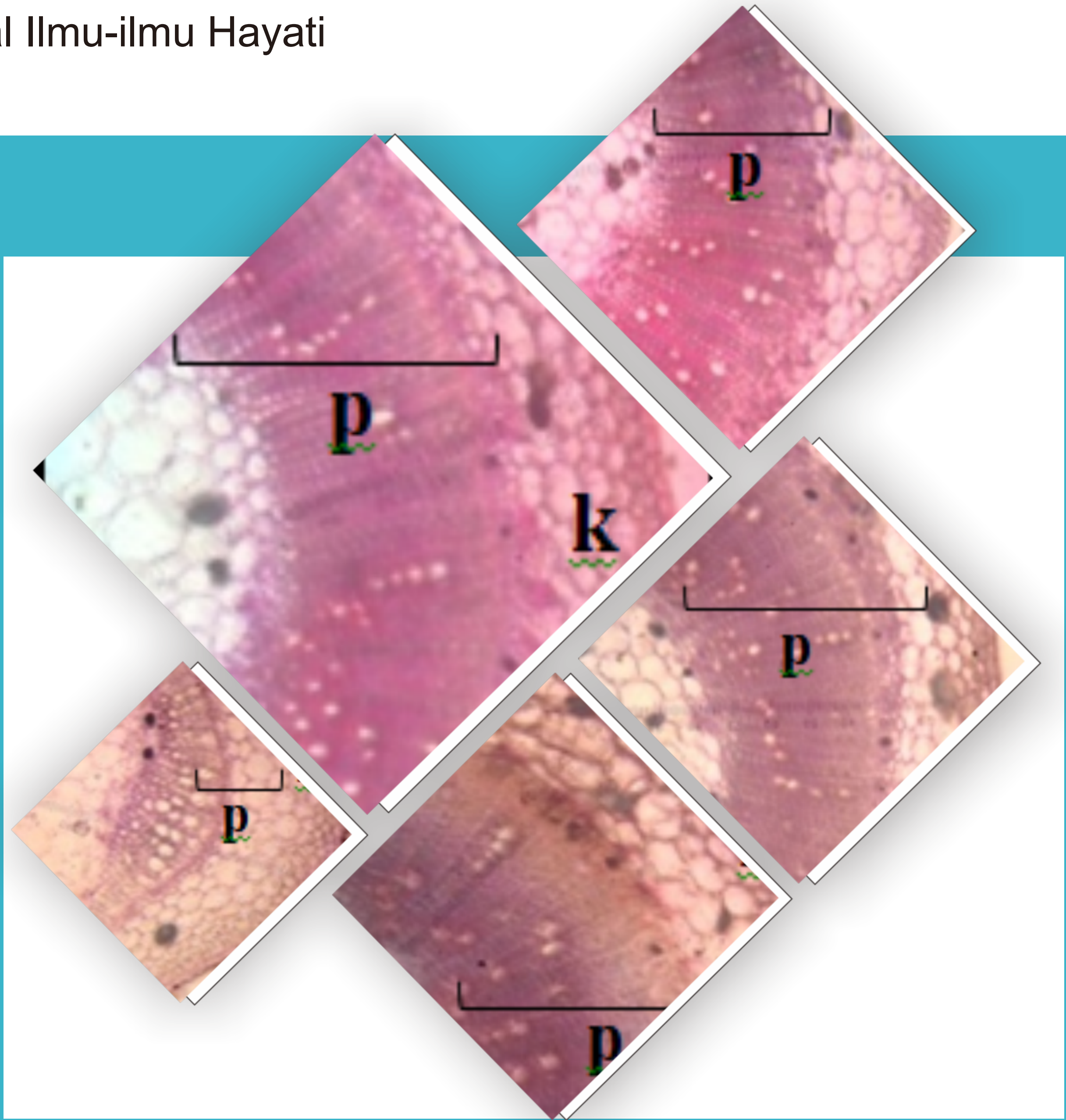

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Keterangan foto cover depan: Efek Cekaman Kromium Terhadap Profil Mikro-anatomi Cabai (*Capsicum annuum* L.)
(*Notes of cover picture*): *Micro-anatomical of the stems structure of 400x magnification.* (Halaman 107)

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THE EFFECT OF CHROMIUM STRESS ON MICRO-ANATOMICAL PROFILE OF CHILI (*Capsicum annuum* L.)

[Efek Cekaman Kromium Terhadap Profil Mikro-anatomi Cabai (*Capsicum annuum* L.)]

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ABSTRACT

Chromium contamination can affect morphological, physiological, and anatomical changes, especially in chili vegetative organs. This research aims to understand micro-anatomical structure of the vegetative organs of chili subjected to chromium stress. The aim of the research is to know whether there is a micro-anatomical character difference between contaminated and uncontaminated chromium. The experimental methods using a completely randomized design (CRD). The independent variable is five levels of chromium concentration, i.e., 0; 50; 100; 200; and 300 ppm. The method of preparing anatomical preparations of the stem using a non-embedding and embedding method. The parameters observed in root and stem are organ diameter, xylem, thick of epidermis, and cortex. In contrast, leaf organ parameter includes thick cuticle, epidermis, mesophyll, stomata size (length and width), and stomatal number. The research results showed that organ anatomical structure, i.e., root, stem, and leaf in chromium stress condition did not change. Chromium deposition causes a decrease in root diameter, xylem, thick cortex roots, stem diameter, xylem, the thickness of the epidermis and cortex, leaf epidermal thickness, mesophyll, size of stomata width and number. In contrast, the chromium stress causes an increase in the thickness of the root epidermis (43,18%), cuticle thickness (36,36%), and leaf stomata length (33,33%) of chili as chromium concentrations increase. The anatomical structure of chili leaves changes after being contaminated chromium stress.

Keywords: *Capsicum annuum*, chromium, micro-anatomy, vegetative organ

ABSTRAK

Cekaman kromium dapat mempengaruhi perubahan morfologis, fisiologis, dan anatomi, terutama pada organ vegetatif tanaman cabai. Tujuan dari penelitian ini adalah untuk mengetahui struktur mikro-anatomi organ vegetatif cabai pada kondisi stres kromium dan karakter anatomi antara terkontaminasi kromium dan tidak terkontaminasi. Metode eksperimental dengan rancangan acak lengkap (RAL). Variabel independen adalah lima tingkat konsentrasi kromium, yaitu, 0; 50; 100; 200; dan 300 ppm. Metode penelitian untuk pengamatan karakter mikro-anatomi menggunakan metod embedding pada daun dan pengamatan mikro-anatomi akar menggunakan metode non-embedding. Parameter yang diamati pada akar dan batang adalah diameter organ, xilem, tebal epidermis, dan korteks. Sebaliknya, parameter organ daun meliputi kutikula tebal, epidermis, mesofil, ukuran stomata (panjang dan lebar), dan jumlah stomata. Hasil penelitian menunjukkan bahwa struktur anatomi organ yaitu, akar, batang, dan daun dalam kondisi stres krom tidak berubah, akan tetapi deposisi kromium menyebabkan penurunan diameter akar, xilem, tebal korteks akar, diameter batang, diameter xilem, ketebalan epidermis dan korteks batang, ketebalan epidermis daun, mesofil, ukuran lebar dan jumlah stomata. Cekaman kromium menyebabkan peningkatan ketebalan epidermis akar (43,18%), tebal kutikula (36,36%), dan panjang stomata (33,33%) daun seiring dengan meningkatnya konsentrasi kromium.

Kata kunci: *Capsicum annuum*, kromium, mikro-anatomi, organ vegetatif

INTRODUCTION

Chili (*Capsicum annuum* L.) can respond to chrome toxicity and begin with the interaction of chrome with plants through absorption. Chrome is non-essential elements for plants and is toxic if the concentration exceeds the threshold. Chrome toxicity can affect a variety of anatomical, physiological, and molecular aspects (Kasmiyati, 2018).

Chromium is a chemical that is toxic, bioaccumulative, and difficult to decompose in the environment. Chromium can inhibit the process of electron transport, enzyme inactivation, disorganization of chloroplasts, and trigger the formation of reactive oxygen species such as oxides, hydrogen peroxide, and hydroxyl (Anugrah, 2014). Chromium stress in plants results in stunted plant growth and development, decreased productivity, and changes in anatomic characters, causing death (Kasmiyati and Sucahyo, 2014). Symptoms of chromium toxicity in plants are inhibition during initial growth, reduction of root growth, leaf chlorosis, and decreased biomass production.

*Kontributor Utama

Chromium can also affect anatomic changes, especially in the vegetative organs (Rahardjo, 2014).

Micro-anatomical character can be used as parameter to determine the effect of a particular substance toxicity on plants. Incoming materials can cause changes to plants, from the individual to the cellular and molecular levels (Lei *et al*., 2007). Research on the effects of chromium toxicity on plant anatomical characters has not explicitly been mapped. Chromium can increase the density of the stomata and reduce the thickness of the mesophyll in the leaves of the *Triticum durum* plant (Vazquez *et al.* 1987). Chromium causes damage to cell structure, reduces cell size and vacuole, and reduces the size and number of xylem and phloem cells in *Phaseolus vulgaris* plants (Rahardjo, 2014).

Plants as phytodegradation as carrying out the metabolism of contaminants with the help of enzymes in plant tissue. Absorption of contaminants and releasing it to air passing through the leaves (Meuser, 2012). Darmawan (2012) reported that the accumulation of chromium in the roots of plants was higher than in the plant canopy for two types of mustards, either good harvested at the age of 3 or 6 weeks after planting. The chromium content in plant tissues of mustard as part of the vegetable that generally consumed exceeds the threshold of daily human consumption (0,035 mg/kg daily consumption).

The great variety of changes in the anatomical character of various plants choked with chromium, attracted researchers to observe changes in the anatomical aspects of chili plants (*C. annuum* L). Chili is a spice vegetable plant, which is an essential commodity in Indonesia. Research on the effects of chromium stress on the anatomical characteristics of roots, stems, and chili leaves has never been done. Changes in the anatomical character of chilies that grow in chromium-contaminated environments will inhibit the growth and development of plants that cause crop failure and impact farmers' losses. The chili seedling accumulated more chromium and became more sensitive under combined application of *S. rolfsii* and Cr(VI), in comparison to the individual stress of either pathogen or metal (Shoaib *et al*., 2019). Chili were used as raw material for the production of low-cost adsorbents for the removal of methylene blue from water (Parra-Marfil *et al*., 2020).

Increased heavy metal pollutants, including chromium in the environment, can cause a decrease in the plants' growth that is not tolerant. The study about crop tolerance's ability to chromium stress, especially *C. annuum* in Indonesia, is still limited. This study aimed to determine the microanatomical structure and changes in the anatomical character of the vegetative organs of chili plants, which were choked with chromium.

MATERIALS AND METHODS

Materials used in this research are potassium dichromate (K2Cr2O7), chili seeds, soil, compost fertilizer, formalin, glacial acetic acid, safranin 1% in 70% alcohol, 96% alcohol, ethanol, xylol, paraffin, distilled water, glycerin, albumin, aluminum foil. The tools used in the study are polybags, small shovels, gloves, objective micrometers, ocular micrometers, square micrometers, measuring cups, beaker glass, flacon bottles, object-glass, cover glass, stationery, label paper, dropper pipettes, ovens, brushes no.2, holder, staining jar, bunsen, hotplate and stirrer, digital scales, thermostats, binocular microscopes, trays, analytical scales, razors, tweezers, rotary microtome, gloves, water distillers and tissue paper. Planting and maintaining chili plants is done at the Green House. Anatomical character observations were carried out at the Laboratory of Plant Structure and Development of the Faculty of Biology, Jenderal Soedirman University. The study conducted in February-June 2018.

Chromium Solution: Cr (VI) stock solution concentration of 1000 ppm was prepared by dissolving 3,735g K2Cr2O7 in 2 mL HNO3 and 988 mL distilled water. The concentration of 50; 100; 200; and 300 ppm made by diluting 15 ppm stock solutions of 15; 30; 60; and 90 mL with a volume of 300 mL. Cr (VI) solution is sprayed on the planting medium. Each treatment repeated five times.

Planting and Maintenance Media: The planting medium used is 1.5 kg of soil mixed with 1.5 kg of compost. Chromium is then poured into the medium and waited two days before the chilies from the seeding transferred to the growing media. Chromium is only splashed once in the planting medium before the chili seedlings removed. Chili is planted and maintained for 25 days. During maintenance, chili is poured with clean water as much as 250 ml / 2 days. Vegetative organs were taken to make anatomical preparations after 25 days. Environmental factors observed were temperature and humidity measured at 7:00 in the morning, noon, and 17:00 WIB at noon and carried out three times a week.

Sample collection: Leaf samples were taken from the fifth leaf from the tip of the chili plant. Root samples were taken from the tip of the primary root with a length of about 1 cm. Stem samples are taken from the stem shoots with a distance of 5 cm from the shoots so that the anatomical structure can be observed due to optimal tissue differentiation (Samiyarsih *et al*., 2019).

Embedding methods for micro-anatomical characters: Fresh leaf was taken and cut into a 1 cm^2 piece. It was then subjected to fixation in the FAA solution(FAA consist of 10% formalin, 5% acetic acid, 50% ethyl alcohol, and aquadest 35%) for 24 hours. Preparation of leaf anatomy based on the embedding method and staining was done using safranin(1%) in 70% alcohol. Transversal and paradermal slices using intact preparation method of fresh leaves, including (1.) the number of trichomes and stomata cells; (2.) stomata and trichome density obtained from the following calculation: stomatal/ trichome density=total stomata/trichomes per area of the field of view(mm^2); (3.) thickness of cuticle, epidermis, and mesophyll, stem and root. Observations were made with a binocular microscope, Olympus CH-20, at 400x magnification. Measurement of anatomical profiles done using a calibrated ocular micrometer (Samiyarsih *et al*., 2020).

Data analysis The data of micro-anatomical characters were analyzed using SPSS with a randomized block analysis of variance (ANOVA) to determine the effect of treatment (chromium dosage) and continued with the LSD test at 5% ($p < 0.05$) and 1% ($p < 0.01$) probability level.

RESULTS

Micro-anatomical characters of roots of *C. annuum* due to chromium stress

Chromium stress in chili has the same anatomical structure as the control but has different anatomical characters. Based on the observations, micro-anatomical structure of chili roots experiencing chromium stress is the same as the control (Figure 1). Chili root is composed constructed by epidermal tissue, cortex, endodermis, and transport tissue. Root epidermal tissue consists of a layer of cells that are tightly arranged, and there is no space between cells. The root cortex consists of parenchymal cells, and in the deepest layer of the cortex, there is endodermis. The roots have a carrier

Table 1. Micro-anatomical characters of root diameter, epidermis thickness, cortex, and root xylem diameter of *C. annuum* due to chromium stress

Chromium dosage (ppm) (Dosis Kro-mium)	Roots diameter (µm) (Diameter akar)	Roots epidermis (µm) (Epidermis akar)	Roots cortex (µm) (Korteks akar)	Roots xylems diameter (µm) (Diameter xylem akar)
0	1006.00±1.2d	17.60±0.33d	194.00±2.7d	38.20±0.33c
50	883.33±1.4c	20.30±0.33c	175.60±2.3bc	32.20±1.00c
100	845.33±2.0bc	22.70±0.67bc	167.10±2.3bc	29.90±0.67bc
200	739.33±1.4b	23.80±1.00b	156.20±2.3ab	26.30±0.33b
300	572.67±2.2a	25.20±0.33a	134.90±2.3a	23.90±0.67a

*Means followed by the same letter are not significantly different at 5% according to the least square different (LSD) test.

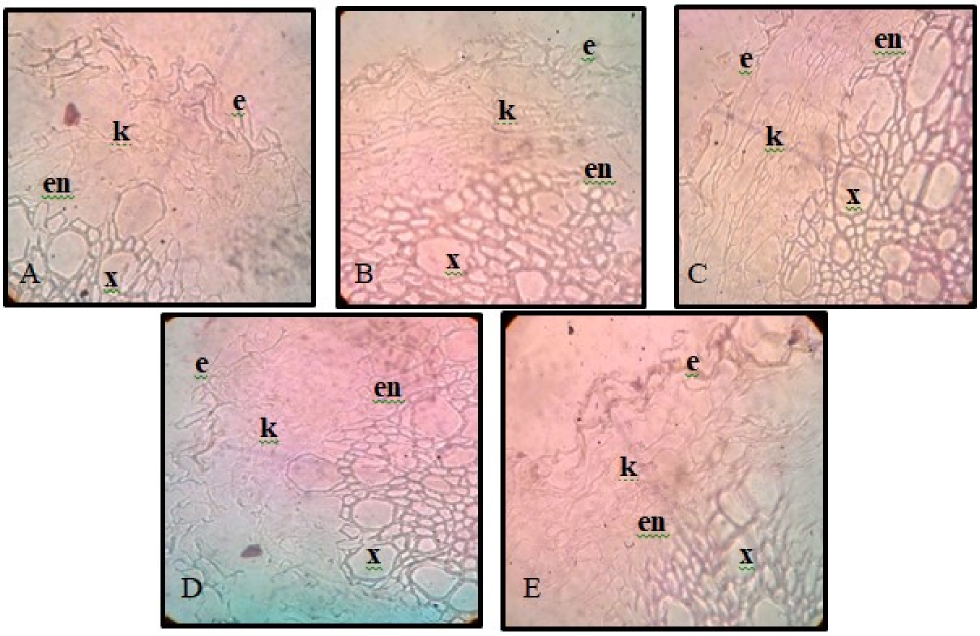

Figure 1. Micro-anatomical of the root structure of 400x magnification. Chromium dosage (A) 0 ppm; (B) 100 ppm; (C) 100 ppm; (D) 200 ppm; (E) 300 ppm; (e) root epidermis; (k) root cortex; (en) endodermis; (x) xylem. (*Struktur mikro anatomi akar perbesaran 400x. Dosis kromium (A) 0 ppm; (B) 100 ppm; (C) 100 ppm; (D) 200 ppm; (E) 300 ppm; (e) epidermis akar; (k) korteks akar; (en) endodermis; (x) xilem.*)

network consisting of xylem and phloem.

The highest mean root diameter is 1006 µm in the control chili, while the lowest root diameter is 572 µm which was found in the chili with 300 ppm chromium stress treatment. The highest average xylem diameter is 38.2 µm in the control root, and the lowest is 23.9 µm in chili with 300 ppm chromium stress. The highest mean cortex thickness is 194 µm in control and lowest in the chromium stress 300 ppm, which is 134.9 µm refer to table 1.

Stems micro-anatomical characters of *C. annuum* due to chromium stress.

The anatomical structure of the chili stem with chromium stress is the same as the control. The structure of the chili stem consists of epidermal tissue, cortex, and transport tissue. Stem epidermal tissue consists of a layer of tightly arranged cells and coated with cuticles on the outside. The chili stem cortex consists of several layers of cells with larger cell sizes compared to epidermal cells. The chili stem transport network is located inside the cortex (Figure 2).

The highest average stem diameter is in the control of 3148.7 µm, and the lowest is in chili with 300 ppm chromium stress, which is 2152 µm. The highest mean thickness of the epidermis is 18.72 µm in control, while the lowest average thickness of the epidermis is in chili with 300 ppm chromium stress, which is 11.6 µm. The highest cortical thickness was found in the roots control, which was 194 µm, and the lowest was the roots of chili plants with chromium stress 300 ppm, which was 134.9 µm. The highest xylem diameter of chili stem was 48.8 µm in control, while the lowest xylem diameter was 32.8 µm in chili pepper, which was stressed with 300 ppm chromium refer to Table 2 and Figure 2.

Leaf of the micro-anatomical characters of *C. annuum* due to chromium stress.

Chili leaf cross-section, chromium leaf anatomy that is given chromium with chili leaves without chromium, has the same anatomical structure, which consists of epidermis covered with a cuticle, mesophyll, and transport beam. However, chromium -stressed chili occurs damage to the epidermis or

Table 2. Micro-anatomical characters of stem diameter, epidermis thickness, cortex, and stem xylem diameter of *C. annuum* due to chromium stress.(*Karakter mikro-anatomi diameter batang, ketebalan epidermis, korteks, dan diameter xilem batang C. annuum akibat cekaman kromium.)*

Chromium dosage stress (ppm) (Dosis cekaman kromium)	Stems diameter (µm) (Diameter batang)	Stems epidermis (µm) (Epdermis batang)	Stems cortex (µm) (Kortek batang)	Stems xylems diameter (µm) (Diameter xylem batang)
0	3168.70±0.34d	18.72±1.7c	232.60±1.1c	48.80±0.9d
50	2956.70±0.15bc	18.20±1.8c	224.64±1.0bc	43.80±0.7cd
100	2660.70±0.22ab	15.90±1.7bc	209.20±1.2bc	40.100±0.9bc
200	2328.00±0.34ab	13.90±1.7ab	196.50±1.2ab	38.00±1.1ab
300	2152.00±0.34a	11.60±1.7a	159.00±1.0a	32.80±0.7a

*Means followed by the same letter are not significantly different at 5% according to the least square different (LSD) test.
* *Nilai yang diikuti oleh huruf yang sama tidak berbeda nyata pada 5% menurut uji Beda Nyata Terkecil (BNT).*

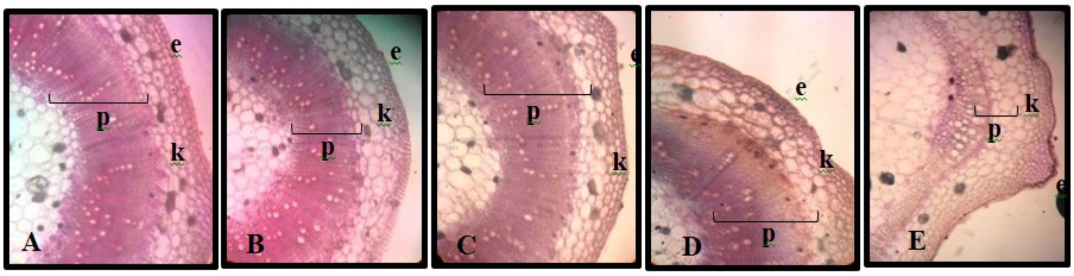

Figure 2. Micro-anatomical of the stems structure of 400x magnification. Chromium dosage (A) 0 ppm; (B) 100 ppm; (C) 100 ppm; (D) 200 ppm; (E) 300 ppm; (e) epidermis; (k) cortex; (p) vesicula transport. (Struktur mikro anatomi batang perbesaran 400x. Dosis kromium (A) 0 ppm; (B) 100 ppm; (C) 100 ppm; (D) 200 ppm; (E) 300 ppm; (e) epidermis; (k) korteks; (p) transportasi vesikula.)

Table 3. Micro-anatomical characters of leaves cuticle thickness, epidermis thickness, mesophyll thickness of *C. annuum* due to chromium stress. (*Karakter mikro-anatomi daun yaitu ketebalan kutikula, tebal epidermis, tebal mesofil C. annuum akibat cekaman kromium*.)

Chromium dosage stress (ppm) (Dosis cekaman kromium)	Cuticle thickness (Tebal kutikula)		Epidermis thickness (Tebal epi-dermis)		Mesophyll thickness (µm) (Tebal mesofil)
	adaxial (µm) (lapisan atas)	abaxial (µm) (lapisan bawah)	adaxial (µm) (lapisan atas)	abaxial (µm) (lapisan bawah)	
0	2,9±0.03a	3,3±0.4a	15,5±1.2cd	11,4±0.08b	195±3.0d
50	3,1±0.03ab	3,5±0.4a	14,9±1.2bc	10,9±0.08ab	179,7±3.2cd
100	3,3±0.02abc	3,8± 0.3ab	11,9±1.1ab	10,2±0.10ab	162,7±3.0abc
200	3,5±0.02 bc	4,1±0.4bc	10,8±1.1a	9,7±0.09ab	151,3±2.9ab
300	3,8±0.03c	4,5±0.4c	9,52±1.1a	8,9±0.08a	139,6±3.0a

*Means followed by the same letter are not significantly different at 5% according to the least square difference (LSD) test.
*Nilai diikuti oleh huruf yang sama tidak berbeda nyata sebesar 5% menurut uji Beda Nyata Terkecil (BNT).

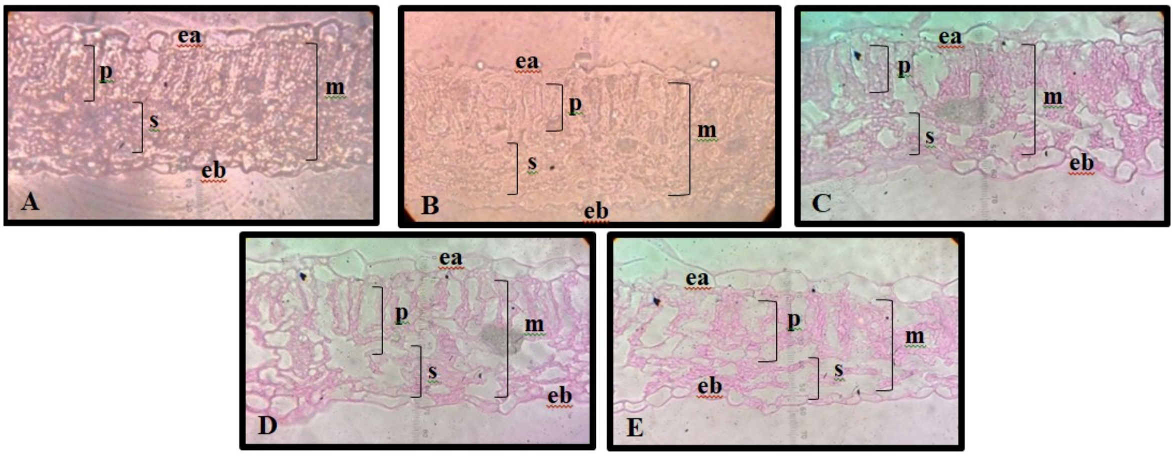

Figure 3. Micro-anatomical of the leaves cross section structure of 400x magnification. Chromium dosage (A) 0 ppm; (B) 100 ppm; (C) 100 ppm; (D) 200 ppm; (E) 300 ppm; (ea) adaxial epidermis; (m) mesophyll; (p) palisade network; (s) sponge tissue; (eb) abaxial epidermis. *(Struktur penampang daun mikro anatomi perbesaran 400x. Dosis kromium (A) 0 ppm; (B) 100 ppm; (C) 100 ppm; (D) 200 ppm; (E) 300 ppm; (ea) epidermis adaxial; (m) mesofil; (p) jaringan palisade; (s) jaringan spons; (eb) epidermis abaksial.)*

Table 4. Micro-anatomical characters of leaves of width, length, and density of stomata of *C. annuum* due to chromium stress. (*Karakter mikro-anatomi daun dari lebar, panjang, dan kerapatan stomata C. annuum akibat cekaman kromium*.)

Chromium dosage stress (ppm)	Stomata length (Panjang stomata)		Stomata width (Lebar sto-mata)		Density of stomata (Kerapatan stomata)	
	Adaxial (µm) (lapisan atas)	Abaxial (µm) (lapisan bawah)	Adaxial (µm) (lapisan atas)	Abaxial (µm) (lapisan bawah)	Adaxial (/mm^2) (lapisan atas)	Abaxial (/mm^2) (lapisan bawah)
0	14.70±0.33a	11.70±0.10a	9.10±0.3d	8.90±0.27c	10.04±1.4c	17.04±1.5 b
50	15.80±0.67a	14.80±0.10b	8.00±0.3cd	8.00±0.25c	9.32±0.7 bc	16.72±1.0b
100	17.20±0.67ab	15.20±0.15b	6.40±0.4bc	7.80±0.25bc	9.04±0.7 bc	15.24±1.5ab
200	18.30±0.33bc	16.40±0.20bc	5.60±0.4ab	5.80±0.27b	8.32±1.4ab	15.08±1.0 ab
300	19.60±0.33c	18.20±0.10c	4.80±0.3a	3.80±0.25a	7.62±0.7 a	13.40±1.0 a

*Means followed by the same letter are not significantly different at 5% according to the least square difference (LSD) test.
*Nilai diikuti oleh huruf yang sama tidak berbeda nyata sebesar 5% menurut uji Beda Nyata Terkecil (BNT).

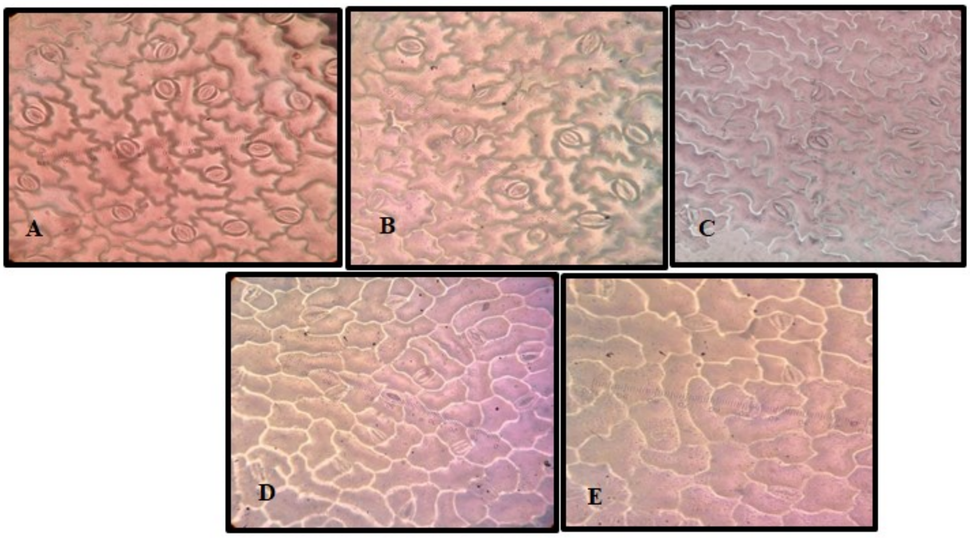

Figure 4. The stomatal profile of the *C.annuum* leaves a paradermal section structure of 400x magnification due to chromium stress. Chromium dosage (A) 0 ppm; (B) 100 ppm; (C) 100 ppm; (D) 200 ppm; (E) 300 ppm. (*Profil struktur stomata daun C. anuum penampang paradermal pembesaran 400x karena tegangan kromium. Dosis kromium (A) 0 ppm; (B) 100 ppm; (C) 100 ppm; (D) 200 ppm; (E) 300 ppm.)*

mesophyll (Figure 3). Cuticle thickness increases linearly with the increase of chromium stress refer to table 3.

Longitudinal cross-section of chili leaves obtained the results that the stomata structure between each chromium treatment there is no difference. However, stomata in chili peppers by giving 0 ppm chromium tend to be more stomata found in the bright conditions. In chili peppers 300 ppm chromium treatment, many stomata in closed conditions (Table 4; Figure 4). This research shows that there is a plant adaptation mechanism to minimize water vapor loss due to transpiration.

Chromium stress causes an increase in the thickness of the root epidermis (43,18%), cuticle thickness (36,36%), and leaf stomata length (33,33%) of chili as chromium concentrations increase (Figure 5, Figure 6). Based on analysis of the increase-decrease of micro-anatomical of vegetative organs of *C. annuum* due to variation of chromium stress dosage given a variation response. The vegetative phase on *C. annum* organs has different micro-anatomic responses to chromium stress. Data analysis showed that the micro-anatomic character of root diameter, cuticle thickness, and stomata length increased in line with the increase in chromium dose.

DISCUSSION

The structure and anatomical character of the vegetative organs of chili give different and varied responses. Changes in micro-anatomic profiles occur in plants due to abiotic stress environment, such as sweet potato leaves due to nitrogen

poisoning (Juwarno *et al*., 2009), mangrove leaves due to metal pollution in water (Samiyarsih *et al*., 2017), soybean leaves due to salinity stress (Juwarno *et al*., 2018), and diversity of snake fruit and sweet potatoes anatomy in the geographical conditions of an area (Herawati *et al*., 2018; Samiyarsih *et al*., 2020).

Chromium-gripped chilies have different anatomical characters. That is because the reduction of Cr (VI) to Cr (III) increases reactive oxygen species. Kasmiyati & Sucahyo (2014), chromium stress impacts the formation of oxides (O_2) and hydrogen peroxide (H2O2), which can damage cell structure and inhibit plant cell division. According

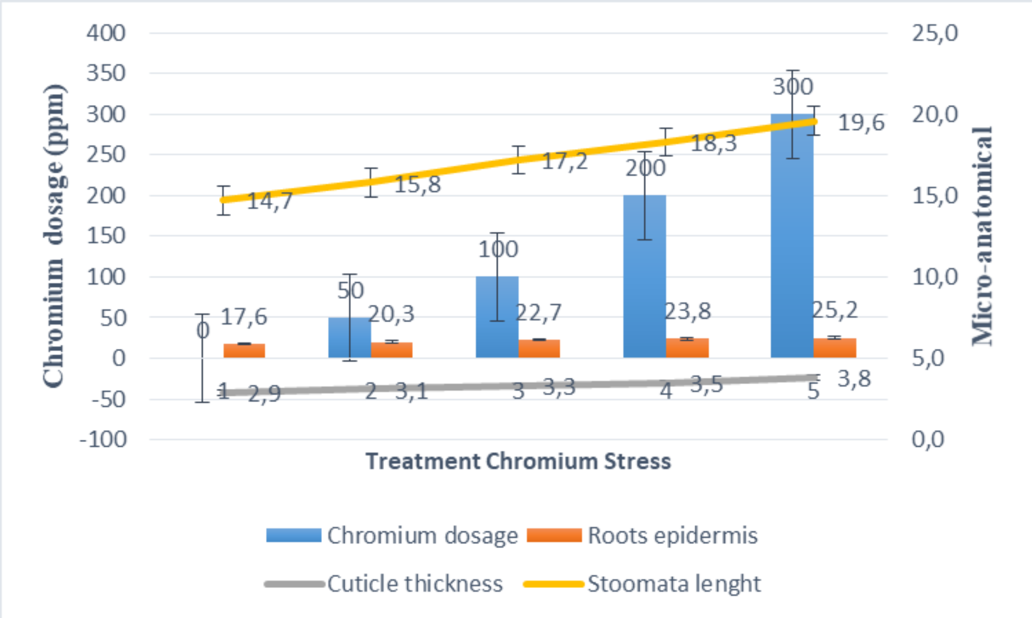

Figure 5. Increase characters of micro-anatomical of vegetative organs of *C. annuum* due to variation of chromium stress dosage. (*Peningkatan karakter mikro-anatomi organ vegetatif C. annuum akibat variasi dosis cekaman kromium)*

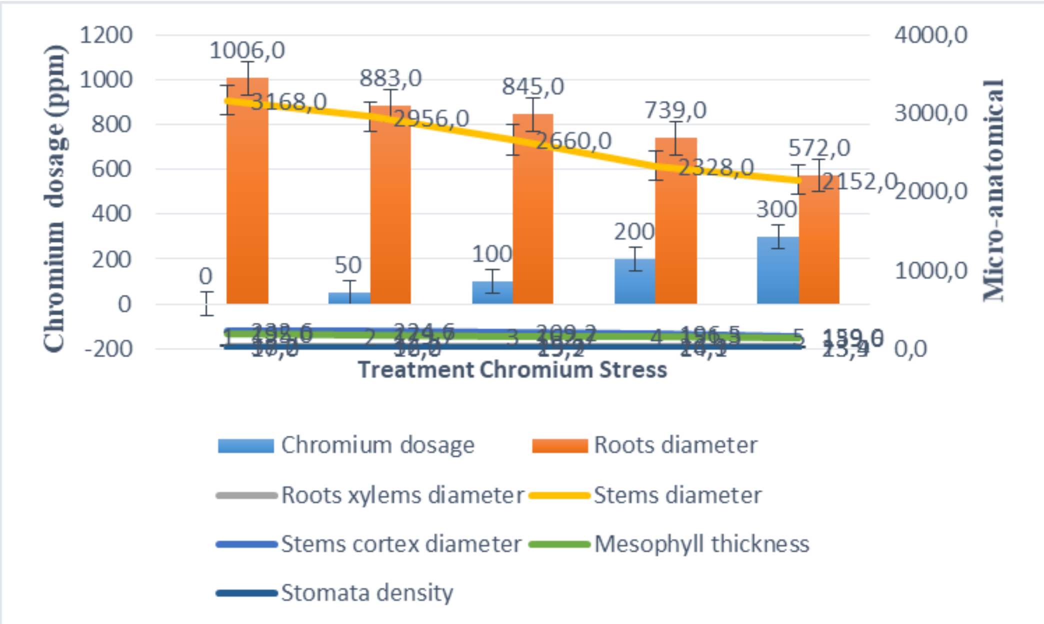

Figure 6. Decrease characters of micro-anatomical of vegetative organs of *C. annuum* due to variation of chromium stress dosage. (*Penurunan karakter mikro-anatomi organ vegetatif C. annuum karena variasi dosis cekaman kromium)*

to Dias *et al*. (2013), chili roots are composed of three primary tissues, namely epidermal tissue, cortex tissue, and transport tissue.

The reduced diameter of the root xylem in chili, which experiences chromium stress, indicates the mechanism of chili adaptation to minimize chromium compounds that absorbed into plants. Vesicula transport tends to be narrower in plants that experience heavy metal stress. One of the effects of chromium toxicity in the soil is the thickening of the epidermis in plant root organs due to chromium accumulation. Chandra *et al*. (2010) and Gupta (2011) reported that plant organs experiencing chromium stress would experience changes or decrease in value compared to plants that do not experience chromium stress. Plants that absorb chromium will experience a decrease in the thickness of the root cortex parenchyma due to inhibited nutrient uptake or distribution of nutrients in plants. Plants absorb chromium through active transport. Gomes *et al*. (2017) reported that the root plasma membrane was the first functional structure to come in direct contact with chromium in polluted soils. Farzadfar & Zarinkamar (2012) reported that the reduction of xylem diameter would reduce water transfer through stomata size reduction.

Increase in the thickness of the root epidermis (43,18%) caused as chromium concentrations increase. The epidermis of the stem is low as the chromium tried higher. Chromium absorbed by chili blocks the process of cell division and elongation so that the epidermal layer tends to become thinner. Rahardjo (2014) reported that in plants exposed to heavy metals, the thickness of the stem epidermis would tend to decrease in response to the accumulation of contamination in plants.

Chromium stress causes an increase in the thickness of cuticle thickness (36,36%). The cuticle of the chili leaves is thicker, indicating the chili's adaptation to inhibit the possibility of water vapor from the leaves. Chromium-chilled chili has less water content in the tissues due to the inhibited water absorption process. Samiyarsih *et al*. (2016) reported that plants adapt to the pollution in their habitat. Tupan & Rodiyati (2016) added that the accumulation of heavy metals in plants could cause the thickness of the leaf cuticles. Chromium accumulation in leaves causes thinning of the epidermis layer. Chromium stress plants have smaller cell sizes. The low level of leaf mesophyll in chromium is choked by chromium due to the cell enlargement process's inhibition due to the chromium the chili leaf tissue. Ariyanti *et al*. (2015) reported that heavy metals in plants could cause mesophyll tissue to become thinner.

Chromium stress will have an impact on the change in size and density of the chili stomata. The stomata's size becomes longer because the chromium-covered chili stomata are mostly found in a closed state to minimize the loss of moisture during the transpiration process. Closed stomata have a more extended size than when stomata are open. Samiyarsih *et al*. (2016) which states that polluted plants have a longer stoma and will quickly lose moisture when the stomata open because of the transpiration process. The stomata density of chromium is reduced due to the occurrence of adaptation to reduce the rate of transpiration. According to de Silva *et al*. (2016), the higher accumulation of heavy metals in a plant will result in a tendency to decrease stomata density, thereby minimizing the loss of excess moisture.

CONCLUSION

Micro-anatomical structure of root organs stems and leaves of chili (*Capsicum annuum* L.) that experience chromium stress does not change, but the quantitative characters are changes. Chromium stress causes a decrease in root, stem, root xylem, and stem xylem diameters. The thickness of the root cortex, epidermis, and cortex of the stem, leaf epidermis, mesophyll, stomata width, and density decreases due to chromium stress. Chromium stress causes an increase in the thickness of the root epidermis (43.18%), cuticle thickness (36.36%), and leaf stomata length (33.33%) of chili as chromium dosage increase.

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Pedoman Penulisan Naskah Berita Biologi

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Tipe naskah

1. **Makalah lengkap hasil penelitian (*original paper*)**
   Naskah merupakan hasil penelitian sendiri yang mengangkat topik yang *up to date*. Tidak lebih dari 15 halaman termasuk tabel dan gambar. Pencantuman lampiran seperlunya, namun redaksi berhak mengurangi atau meniadakan lampiran.
2. **Komunikasi pendek (*short communication*)**
   Komuniasi pendek merupakan makalah hasil penelitian yang ingin dipublikasikan secara cepat karena hasil termuan yang menarik, spesifik dan atau baru, agar dapat segera diketahui oleh umum. Hasil dan pembahasan dapat digabung.
3. **Tinjauan kembali (*review*)**
   Tinjauan kembali merupakan rangkuman tinjauan ilmiah yang sistematis-kritis secara ringkas namun mendalam terhadap topik penelitian tertentu. Hal yang ditinjau meliputi segala sesuatu yang relevan terhadap topik tinjauan yang memberikan gambaran '*state of the art*', meliputi temuan awal, kemajuan hingga issue terkini, termasuk perdebatan dan kesenjangan yang ada dalam topik yang dibahas. Tinjauan ulang ini harus merangkum minimal 30 artikel.

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2. **Judul**
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   Hasil memuat data ataupun informasi utama yang diperoleh berdasarkan metoda yang digunakan. Apabila ingin mengacu pada suatu tabel/ grafik/diagram atau gambar, maka hasil yang terdapat pada bagian tersebut dapat diuraikan dengan jelas dengan tidak menggunakan kalimat 'Lihat Tabel 1'. Apabila menggunakan nilai rata- rata maka harus menyertakan pula standar deviasinya.
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   Bagian ini berisi ucapan terima kasih kepada suatu instansi jika penelitian ini didanai atau didukungan oleh instansi tersebut, ataupun kepada pihak yang membantu langsung penelitian atau penulisan artikel ini.
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   Tabel diberi judul yang singkat dan jelas, spasi tunggal dalam bahasa Indonesia dan Inggris, sehingga Tabel dapat berdiri sendiri. Tabel diberi nomor urut sesuai dengan keterangan dalam teks. Keterangan Tabel diletakkan di bawah Tabel. Tabel tidak dibuat tertutup dengan garis vertikal, hanya menggunakan garis horisontal yang memisahkan judul dan batas bawah.
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