INTISARI

Peningkatan polutan logam berat termasuk krom (Cr) di lingkungan, dapat menimbulkan penurunan pertumbuhan pada tanaman yang tidak toleran. Kemampuan toleransi tanaman pangan terutama *Sorghum bicolor* terhadap cekaman Cr belum banyak diteliti di Indonesia. Tujuan penelitian untuk mengkaji: (1) kemampuan toleransi beberapa kultivar sorgum terhadap cekaman Cr^{6+} dan Cr^{3+} pada fase perkecambahan dan pertumbuhan awal kecambah, (2) mekanisme toleransi dari kultivar toleran dan sensitif terhadap kondisi cekaman Cr^{6+} dan Cr^{3+} berdasarkan respon fisiologis, anatomis, biokimia dan molekular.

Penelitian dilakukan dalam 2 tahap yaitu: (1) seleksi toleransi 12 kultivar sorgum terhadap cekaman Cr^{6+} dan Cr^{3+}, dan (2) uji mekanisme toleransi sorgum yang toleran dan sensitif terhadap Cr^{6+} dan Cr^{3+} hasil seleksi tahap pertama. Seleksi toleransi sorgum terhadap cekaman Cr dilakukan pada 12 kultivar yang diperoleh dari Balai Besar Penelitian dan Pengembangan Bioteknologi dan Sumber Daya Genetik Pertanian (Bogor) dan Balai Penelitian Tanaman Serealia (Maros). Senyawa Cr^{6+} ($K_2Cr_2O_7$ dan K_2CrO_4) dan Cr^{3+} ($CrCl_3$ dan $KCr(SO_4)_2$) pada berbagai konsentrasi digunakan sebagai perlakuan. Seleksi toleransi didasarkan pada nilai *Stress Tolerance Index* (STI), akumulasi dan transformasi Cr pada fase perkecambahan dan pertumbuhan kecambah awal. Uji mekanisme toleransi dilakukan pada 3 kultivar yang telah diseleksi sebelumnya yaitu Numbu dan Keris M3 (toleran) dan Kawali (sensitif). Ketiga kultivar sorgum diuji respon fisiologi, anatomi, biokimia, dan molekular yang berkaitan dengan mekanisme toleransinya terhadap cekaman Cr^{6+} dan Cr^{3+}. Parameter yang diukur yaitu pertumbuhan daun, tinggi batang, berat basah dan berat kering, pigmen fotosintetik, struktur anatomis daun, batang dan akar, akumulasi Cr, kandungan senyawa antioksidan (prolin, asam askorbat, glutation, non protein thiol), aktivitas enzim antioksidatif (CAT, APX, SOD dan GR), serta profil protein SDS-PAGE. Data penelitian dianalisis menggunakan ANOVA (analisis sidik ragam) dan uji DMRT (*Duncan Multiple Range Test)* taraf uji 5%

Hasil seleksi dari 12 kultivar sorgum terhadap cekaman Cr^{6+} dan Cr^{3+} pada fase perkecambahan dan pertumbuhan kecambah awal menghasilkan 8 kultivar sorgum toleran (Mandau, UPCA, Badik, Keris, Keris M3, Numbu, Sangkur, Hegari dan Batari) dan 3 kultivar sensitif (Selayer, Gambela dan Kawali). Kultivar Numbu tergolong paling toleran dan Kawali paling sensitif. Kultivar sensitif Kawali mengalami penurunan pertumbuhan (kecambah awal dan tanaman) serta perubahan struktur anatomis lebih besar dibandingkan kultivar toleran Numbu dan Keris M3 pada cekaman Cr^{3+} dan Cr^{6+}. Kultivar sorgum toleran mengalami klorosis dan cekaman oksidatif lebih tinggi dibanding kultivar sensitif pada cekaman Cr^{6+} dan Cr^{3+}. Kandungan senyawa antioksidan (prolin, asam askorbat, GSH dan NPT) dalam akar kultivar toleran lebih tinggi dibanding kultivar sensitif pada cekaman Cr^{6+} dan Cr^{3+}, sedangkan aktivitas enzim antioksidatifnya (CAT, APX, SOD, dan GR) lebih rendah. Kandungan senyawa antioksidan dan aktivitas enzim antioksidatif pada daun kultivar sensitif lebih tinggi dibanding kultivar toleran pada cekaman Cr^{3+} dan Cr^{6+}. Kultivar sorgum

Numbu memiliki kemampuan mengakumulasi dan mentranslokasi Cr ke bagian pucuk paling besar dibanding Keris M3 dan Kawali. Sorgum kultivar toleran (Keris M3 dan Numbu) dan sensitif (Kawali) mampu mentransformasi bentuk Cr, baik melalui reaksi reduksi (Cr^{6+} menjadi Cr^{3+}) dan oksidasi (Cr^{3+} menjadi Cr^{6+}). Transformasi Cr melalui reaksi reduksi lebih besar dibanding oksidasi. Kemampuan mengoksidasi Cr dari ketiga kultivar sorgum adalah Keris M3 > Kawali > Numbu, dan kemampuan mereduksi Cr adalah Kawali > Numbu > Keris M3. Profil protein SDS-PAGE akar, daun dan biji dari 3 kultivar sorgum mengalami perubahan akibat cekaman Cr. Jumlah pita protein akar, daun dan biji dari 3 kultivar sorgum pada perlakuan Cr mengalami penurunan dibanding kontrol.

Kata kunci: cekaman, logam berat, krom heksavalen, krom trivalen, *Sorghum bicolor*

ABSTRACT

Increased heavy metal pollutants, including chromium (Cr) in the environment, can cause a decrease in the growth of the plants that are not tolerant. The study about ability of crop tolerance to chromium stress, especially *Sorghum bicolor* in Indonesia is still limited. The aims of this research is to investigate: (1) tolerance ability of some sorgum cultivars toward Cr^{6+} and Cr^{3+} stresses in germination and early seedling growth stages, (2) tolerance mechanism of tolerant and sensitive sorgum cultivars toward Cr^{6+} and Cr^{3+} stresses condition based on physiological, anatomical, biochemical, and molecular responses.

The research was conducted in two steps: (1) tolerance selection of 12 sorgum cultivars toward Cr^{6+} and Cr^{3+} stress, and (2) tolerance mechanism test of tolerant and sensitive sorgum cultivars toward Cr^{6+} and Cr^{3+} stress from the selection result. Sorgum tolerant selection toward Cr stress was done to 12 sorgum cultivars obtained from Indonesian Center for Agricultural Biotechnology and Genetic Resources (Bogor) and Indonesian Cereals Research Institute (Maros). Cr^{6+} ($K_2Cr_2O_7$ and K_2CrO_4) and Cr^{3+} ($CrCl_3$ and $KCr(SO_4)_2$) compounds in several concentration levels were used as the treatment. Tolerant selection was based on Stress Tolerance Index (STI) value, Cr accumulation and transformation in germination and early seedling growth stages. Tolerance mechanism test was done to 3 selected cultivars: Numbu and Keris (the tolerant), and Kawali (the sensitive); seeking for their physiological, anatomical, biochemical, and molecular responses related with their toleranse mechanism toward Cr^{6+} and Cr^{3+} stresses. The parameter measured were leaves growth; stem height; fresh and dried weights; photosyntetic pigments; leaf, stem, and root anatomical structures; Cr accumulation; antioxidant compounds (proline, ascorbic acid, glutathione, non protein thiol); antioxidative enzymes activity (CAT, APX, SOD and GR); and SDS-PAGE protein profiles. The data were analyzed using Analysis of Variance (ANOVA) and Duncan Multiple Range Test (DMRT) with 5% test level.

The selection resulted in finding 8 tolerant sorgum cultivars (Mandau, UPCA, Badik, Keris, Keris M3, Numbu, Sangkur, Hegari, and Batari) and 3 sensitive cultivars (Selayer, Gambela, and Kawali). Numbu was considered the most tolerant cultivar, while Kawali was the most sensitive one. Kawali experienced growth decrease (both early seedling and plant phases) and more anatomical structure changes compared to Numbu and Keris M3. Tolerant sorgum cultivars suffered chlorosis and oxidative stress higher than the sensitive ones. Antioxidant compounds (proline, ascorbic acid, glutathione, non protein thiol) in the root of tolerant cultivars was found higher than the sensitive ones, while antioxidative enzymes activity (CAT, APX, SOD, and GR) was lower. Meanwhile, the antioxidant compounds and antioxidative enzymes activity found in the leaf of sensitive cultivar were higher than the tolerant ones. Numbu has the ability to accumulate and translocate Cr to the shoot higher than Keris M3 and Kawali. Both tolerant (Keris M3 and Numbu) and sensitive (Kawali) cultivars were able to transform Cr through reduction (Cr^{6+} to Cr^{3+}) and oxidation (Cr^{3+} to

Cr^{6+}) reactions. Cr transformation through reduction was higher than oxidation reaction. Cr oxidation ability of the 3 cultivars can be read as follows: Keris M3 > Kawali > Numbu. While the Cr reduction ability was Kawali > Numbu > Keris M3. SDS-PAGE protein profiles in the roots, leaves and seeds of three cultivars of sorghum were altered by Cr stress. Number of protein bands in roots, leaves and seeds of three cultivars of sorghum on the treatment of Cr decreased while compared with control plants.

Keywords: stress, heavy metal, hexavalent chromium, trivalent chromium, *Sorghum bicolor*