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DROUGHT PROTECTION OF WATERMELON SHOOT GROWTH BY ARTIFICIAL COVER MULCHES

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SUMMARY: In order to explain how mulch regulates watermelon (Citrullus lanatus (Thunb.) Matsum. & Nakai) shoot growth under dehydration, white and red polyethylene film and black non-woven textile were tested. Plants on black non-woven textile and red polyethylene foil showed the lowest shoot growth reduction, and this can be ascribed mainly to water saving properties of these cover mulches. However, important role could be played by modified light and temperature environment, as well.

Key words: *watermelon, artificial cover mulch, drought, shoot growth, water regime.*

INTRODUCTION

Cultivation technologies of many vegetable crops (sweet pepper, tomato, cucumber, watermelon, etc.) include application of artificial cover mulches (Carranca, 2006). Besides the positive effect on biomass/fruit production (Diaz-Perez and Batal, 2002), they also improve fruit quality (Farias-Larios and Orozco-Santos, 1997), and regulate pest development (Diaz-Perez et al., 2007; Fortnum et al., 2000; Webster, 2005). However, in conditions of climate changes and global warming, drought protective properties emerge, as well (Xie et al., 2005).

Formulating practical rules for farmers requires great experimental effort. Studying effects on production and its quality must be accompanied by a detailed explanation of principles which enable further technological improvement. Proposing experimental design, more attributes regarding artificial cover mulch must be followed: material, porosity, thickness and colour. Colour determines light as well as temperature environment, which is modified by material with certain porosity and thickness, defining range of water and energy fluxes (Tarara, 2000). Therefore, soil and atmospheric

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parameterization is essential. An important element of the system is a species/genotype with concrete trait collection. Generally, space-time dynamics of environmental factors should be moved by mulch more closely to plant optimum. On the other hand, mulch-related shift to suboptimal conditions could contribute to plant hardening. Thus, to get a complete picture, plant physiological responses have to be recorded.

This study is intended to explain whether the principal factor enabling shoot growth of extremely drought tolerant watermelon plants (Yoshimura et al., 2008) is water saving ability of the mulch and whether it is provided by osmotic adjustment, or the if key factors are associated with changes in light and temperature environment.

MATERIAL AND METHODS

Plant material, cultivation and treatment

Watermelon (Citrullus lanatus (Thunb.) Matsum. & Nakai) seedlings of Paladin F1 hybrid (Sakata Seed corp., Japan) with 4 right leaves were prepared in June 2008, under external conditions using substrate AB Extra for Vegetables (Agro CS a.s., Czech Republic). Thereafter, they were transplanted into 5 litres-plastic pots with Potgrond H substrate (Klasmann-Deilmann GmbH, Germany) covered by 50 µm thick red (Maxithen HP 431641) or white (Maxithen HP 15101) coloured polyethylene film Bralen RA 2-63 (Plastika a.s., Slovakia), or by black non-woven textile (Milmar s.r.o., Czech Republic). To establish homogenous light conditions for whole above-ground plant part, the same material was laid under the pots (under non-covered control pots transparent plastic film was applied). During vegetation, water supply and pest management were provided.

Physiological measurements

After 20 days of growth, water was withheld to watermelon plants. At the beginning and the end of dehydration sequence (when sustained wilting was observed, after 8 days) these physiological parameters were determined:

- cumulative shoot length (CSL) (sum of main shoot and branches lengths), enabling calculation of CSL difference
- 2 p.m.-relative water content (RWC) of the youngest expanded leaf in main stem according to formula:
  $$RWC = ((w_{act} - w_{dw}) / (w_{sat} - w_{dw})) \ . \ 100(\%)$$
  where w_{act} – actual sample weight (g), w_{sat} – sample weight in water saturated state (g), and w_{dw} – sample dry weight (g)
- 2 p.m.-osmotic potential (OP, MPa) of this leaf refractometrically; linear regression between index of refraction and calculated osmotic potential of sucrose solutions with increasing concentration at room temperature was:
  $y = -0{,}075x$

After dehydration cycle, leaf osmotic adjustment (OA, MPa) of the youngest expanded leaf in main stem was calculated following method of Morgan (1992), which specifies participation of drought-induced cell content concentration in osmotic potential:

$$OP_0 = OP_w ((RWC_w/100) / (RWC_d/100)) \quad (MPa),$$

where OP_0 – concentration effect in osmotic potential (MPa), OP_w – osmotic potential of well watered leaf (MPa), RWC_w – relative water content of well watered leaf (%), RWC_d – relative water content of dehydrated leaf (%)

$$OA = OP_d - OP_0 \qquad \text{(MPa)},$$

where OP_d - osmotic potential of dehydrated leaves (MPa).

Statistical analysis

Obtained data were submitted to analysis of variance (ANOVA) using application Statgraphics Plus v. 4.0 and MS Excel. LSD tests on confidence level 99 percent were performed for cumulative shoot length, CSL difference, relative water content, osmotic potential and osmotic adjustment. Between RWC at the end of dehydration and CSL difference, linear regression was drawn and coefficient of determination (R2) calculated.

RESULTS AND DISCUSSION

Shoot growth of watermelon plants under sufficient water supply was positively influenced by mulch (Figure 1). However, the only significant difference in cumulative shoot length against non-mulched control plants was observed in white foil-mulched individuals (round 50 cm in average). Black non-woven textile and red foil had moderate effect on cumulative shoot length. Dehydration changed the shoot growth proportions in favour of red foil-mulched plants (in average, approximately 260 cm), but analyzing cumulative shoot growth difference, significant increase was exhibited only with plants on black non-woven textile (Figure 2).

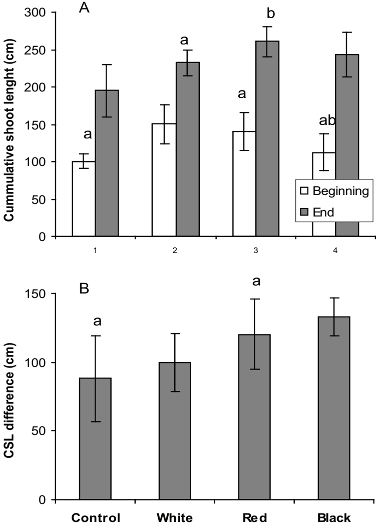

Figure 1: Cumulative shoot length (CSL) of mulched watermelon plants at the beginning and the end of dehydration cycle (A), and difference between them (B). Letters indicate statistically significant difference at P=0.01. Control – non-mulched plants, white – plants mulched by white polyethylene film, red – plants mulched by red polyethylene film, and black – plants mulched by black non-woven textile.

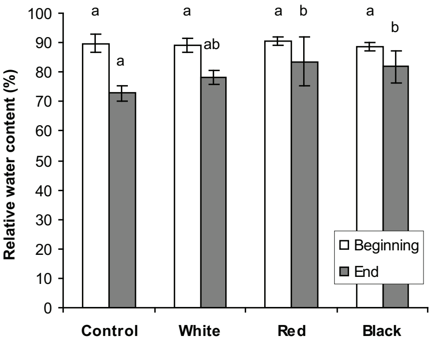

Figure 2: Relative water content of the youngest expanded leaf in main shoot of mulched watermelon plants, as influenced by dehydration. Letters indicate statistically significant difference at P=0.01. Control – non-mulched plants, white – plants mulched by white polyethylene film, red – plants mulched by red polyethylene film, and black – plants mulched by black non-woven textile.

Treatment equilibrium in leaf relative water content (RWC) at the beginning of dehydration (at about 90 %) moved to mulch-based fluctuation at the end of dehydration period (Figure 3). The highest values were found both in plants mulched by black non-woven textile and red foil (in average, 82% and 84 %, respectively). In non-mulched plants RWC fell to approximately 73 %. Similarly, although the initial leaf osmotic potential was equal in every treatment, after dehydration red foil- and black non-woven textile-mulched plants showed the highest values (Figure 4). However, on white plastic film the values were slightly lower than in non-mulched control. Subtracting participation of dehydration-mediated cell content concentration in final osmotic potential showed a large variability but no difference in mean leaf osmotic adjustment (OA) of watermelon plants (Figure 5), pointing to no influence of applied mulches. In spite of this, we found a correlation between relative water content and the cumulative shoot growth difference (coefficient of determination $R^2 = 0.57$, Figure 6).

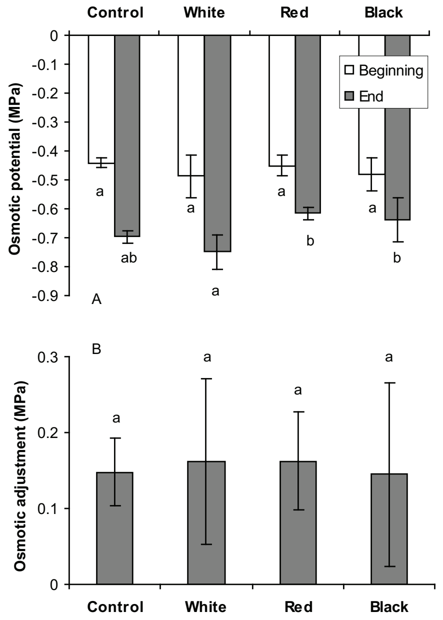

Figure 3: Changes in osmotic potential of the youngest expanded leaf in main shoot under dehydration, as modified by mulch (A), and osmotic adjustment of this leaf evoked by dehydration (B). Letters indicate statistically significant difference at P=0.01. Control – non-mulched plants, white – plants mulched by white polyethylene film, red – plants mulched by red polyethylene film, and black – plants mulched by black non-woven textile.

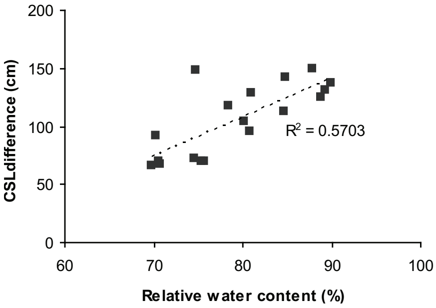

Figure 4: Linear regression between relative water content of the youngest expanded leaf in main shoot at the end of dehydration and cumulative shoot growth difference of watermelon plants mulched by different material.

Shoot growth is the result of genotype traits and a complex of physico-chemical and biological soil and atmosphere characteristics. Mulches markedly influence light, temperature and moisture environment in the field. Although in the first phase there was no limit of water supply in our experiment, light composition as well as temperature dynamics near the mulch surface might affect the cumulative shoot length of watermelon plants.

Application of red plastic mulch enhances red light reflection, thus, increasing the proportion of red light at the shoot level. Due to better absorption and utilization efficiency of this light (Sanchez and Quiles, 2006), higher photosynthetic rate and assimilate production can be expected. On the other hand, changing ratio of red/far red (R/FR) light leads to reduced shoot elongation and branched habitus (Salisbury and Ross, 1991). In this context, wavelength of the reflected red light is also important, since for phytochrome activation followed by a growth response the specific light wavelength (660 nm) is required (Orzolek and Otjen, 2005). However, temperature could also play an important role. Relatively high colour intensity (Diaz-Perez and Batal, 2002), and low evaporation (Xie et al., 2005), attributed to this mulch, make watermelon plants prone to heat stress (Rivero et al., 2003), which limits photosynthesis and growth but accelerates tissue respiration (Wahid et al., 2007). Black non-woven textile represents a completely different mulching material. Dark colour with small reflection coefficient causes almost complete light absorption and transformation to long-wave radiation (Diaz-Perez and Batal, 2002; Diaz-Perez et al., 2007). Unlike polyethylene film, porous structure of this material enables cooling through evaporation. White plastic mulch might increase light input (of whole spectrum) and slightly increase root-zone temperature (RTZ), as well (Diaz-Perez et al., 2007). Therefore, reduced evaporation is expected. In comparison to non-mulched control, proportion of FR light could be markedly decreased.

Twenty days of shoot growth on distinct mulches under sufficient water supply revealed differences: the lowest values of cumulative shoot length were found in non-mulched plants, while significantly higher values were exhibited only in plants mulched by white polyethylene film. Saleh et al. (2003) demonstrated that among red, blue, violet and yellow-green plastic mulch, the highest cucumber (*Cucumis sativus* L.) plant length, total leaf area, total fruit weight as well as air temperature, humidity and soil temperature were achieved on red mulch. Ibarra-Jimenez et al. (2008) amend a positive relationship between RZT, as influenced by mulch, photosynthetic rate and fruit yield. In case of tomato *(Lycopersicon esculentum* L.), Diaz-Perez and Batal (2002) showed a strong negative correlation between light reflectance of mulching foil colour (decreasing from white, silver through grey, red to black) and root zone temperature, and a positive quadratic relationship of RTZ and vegetative top fresh weight, fruit yield, fruit number and individual fruit fresh weight. However, in our former greenhouse experiment (Ferus et al., 2009), no such regression was observed in watermelon plants. Thus, rhizosphere temperature might be a central element in aboveground growth regulation under mulching. For our present results, this is true only when we think of protective effect against excessive summer temperatures. The difference between day and night temperatures may also play a role in water melon shoot growth. Negative “DIF regime” (nights warmer than days) reduced watermelon internode length (Kwon et al., 1999). However, works describing energy balance in mulched canopies are missing.

Successive dehydration changes the complex interaction of mulched plants with their environment. Water deficit slows down/stops growth mainly through loss of turgor, essential for cell expansion (Larcher, 2003). In its later stages, when tissue cooling by transpiration (as well as photosynthesis) is decreased or ceased, a large heat stress can also occur. On the other hand, mulches reduce non-effective evaporation and postpone development of water deficit (Kirnak et al., 2003; Kaya et al., 2005). In this context, plastic mulches can save more water than porous ones. However, the water-saving ability of mulched species/genotype is also important.

Watermelon exhibits an extraordinarily high drought tolerance. It is able to oscillate between survival strategies: at the early stage of drought stress, root development is significantly enhanced (drought avoidance), while at the later stage lignin synthesis-related proteins and molecular chaperones, increasing desiccation tolerance, are induced (Yoshimura et al., 2008). Moreover, there is a large diversity in watermelon growth intensity (Dittmar et al., 2009), and this parameter might determine its drought tolerance, as well. Vigorous (and probably less drought tolerant) hybrid Paladin F1 showed sustained wilting, reflected in reduced relative water content (RWC), after eight days of dehydration. However, black non-woven textile and red foil significantly alleviated water loss from the substrate as well as RWC of the youngest expanded leaf in the main stem. This phenomenon was not associated with osmotic adjustment, pointing to undergoing first survival strategy. Under severe drought, watermelon accumulates high concentration of osmoprotective citrulline, glutamate and arginine in leaves (Yokota et al., 2002).

The highest values of cumulative shoot length were recorded at the end of dehydration period, and its differences were observed in plants on red polyethylene foil and black non-woven textile – though significant increase in these parameters against the non-mulched control was found on red plastic foil and black non-woven textile, respectively. Relatively high determination coefficient of the regression between RWC and cumulative shoot length difference suggests the key position of mulch water saving ability in shoot growth stabilization under drought. Nevertheless, there is an important part of variability, which could be associated with other ways of growth control, possibly light and temperature. And it is also likely that the actual weather or local climate have relatively large participation in mulch-regulated shoot growth (Locher et al., 2005; Ibarra-Jimenez et al., 2008). In our experiment, the dehydration proceeded under relatively cold and changing weather.

CONCLUSIONS

Among tested artificial cover mulches, shoot growth of watermelon plants was mostly preserved by black non-woven textile and red polyethylene foil under drought. In this context, their water saving ability represents the most important trait, though modifications in light and temperature environment can also play an important role.

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ZAŠTITA RASTA IZDANAKA LUBENICE OD DEHIDRACIJE PRIMENOM VEŠTAČKIH PREKRIVAČA

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Izvod

Ispitivan je uticaj belog i crvenog polietilenskog, kao i crnog netkanog tekstilnog prekrivača, na rast i zaštitu od dehidracije izdanaka lubenice *(Citrullus lanatus (Thunb.) Matsum & Nakai)*. Najmanje smanjenje rasta, ustanovljeno je kod biljaka prekrivenih crnim tekstilnim i crvenim polietilenskim prekrivačem. Ovo se može pripisti dobroj sposobnosti ovih prekrivača da spreče dehidraciju. Osim toga, važnu ulogu može imati i stepen propuštanja svetlosti, kao i ambijentalna temperatura.

Ključne reči: lubenica, veštački prekrivač, suša, rast izdanaka, vodni režim.

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