BIO Web of Conferences **202**, 03009 (2025) https://doi.org/10.1051/bioconf/202520203009
ICB3 2025

Morphophysiological response of Indonesian red pepper varieties (*Capsicum annuum*) under drought stress

*Desak Made Lestar*i Dewi[1], *Adilla Lathiifatun* Jannah[1], *Awik Puji Dyah* Nurhayati[1], *Luh Ade Wilan* Krisna[2], *Eita* Uezono[3], and *Nurul* Jadid[1*]

[1]Department of Biology, Institut Teknologi Sepuluh Nopember, 60111 Surabaya, East Java, Indonesia
[2]Department of Medical Laboratory Technology, Politeknik Kesehatan Kementerian Kesehatan, 80244 Denpasar, Bali, Indonesia
[3]Department of Urology, Kumamoto University, 860-8555 Kumamoto, Japan

Abstract. Red chili (*Capsicum annuum*) is a globally important horticultural crop valued for bioactive compounds including capsaicin, flavonoids, and antioxidants. Drought stress is a major abiotic factor limiting chili productivity, yet the morphophysiological responses of different varieties under water deficit are not well understood. This study evaluated four chili varieties Ciko, Lembang 1, Tanjung 2, and Lingga exposed to 14 days of drought stress, while control plants were irrigated daily. Plant height and root length were measured to assess morphological responses, and relative water content, total chlorophyll, and carotenoid levels were determined using spectrophotometry to assess physiological responses. Drought stress significantly reduced plant height, relative water content, and total chlorophyll in all varieties, with Lingga showing the greatest reductions and Ciko the least. In contrast, root length slightly increased, reflecting an adaptive strategy for improved water acquisition. Carotenoid content remained relatively stable, indicating a protective role against oxidative stress. These findings reveal varietal differences in drought tolerance and highlight key morphophysiological traits that confer resilience. Understanding these responses provides a foundation for breeding and selecting drought-tolerant chili cultivars to sustain productivity under climate variability.

1 Introduction

Red chili (*Capsicum annuum*) is among the most important vegetable and spice crops worldwide. It is commonly utilized in both dried and fresh forms, with approximately 80% consumed at the household level and the remaining 20% processed by the food industry. This valuable horticultural commodity provides numerous health and nutritional benefits, as it contains essential nutrients such as proteins, fats, carbohydrates, calcium, phosphorus, iron, vitamins, and bioactive alkaloid compounds, including capsaicin, flavonoids, and essential oils. Moreover, red chili is a rich source of antioxidants and phenolic compounds. According

*Corresponding author : nuruljadid@bio.its.ac.id

to the Directorate General of Horticulture (2018), Indonesia produced 120,673.73 tons of chili in 2018, with a harvested area of 136,857 hectares. Indonesia ranks as the fourth-largest chili producer globally, after China, Mexico, and Turkey; however, its productivity remains lower than that of China, which reached 21.89 tons per hectare [1][2][3][6].

Plant productivity is influenced by internal factors—primarily genotypic traits—and external factors, which include biotic stresses (pests and diseases) and abiotic stresses such as salinity, temperature extremes, and drought. Climate change has intensified these stresses, causing prolonged droughts, floods, and waterlogging that reduce agricultural output. Data from the Directorate General of Food Crops (2018) reported that 127,101 hectares of rice fields in Indonesia were affected by drought, with 25,405 hectares experiencing total crop failure, while the National Disaster Management Agency (2019) identified West Java, Central Java, and East Java as the most impacted regions. Drought stress arises when soil and atmospheric humidity are low and temperatures increase, creating an imbalance between evapotranspiration and root water absorption [4][5][6].

The impact of drought has intensified as water demand from non-food sectors increases, while soil water-holding capacity and environmental quality continue to decline. Drought disrupts plant metabolism by inhibiting nutrient uptake, suppressing cell division and enlargement, reducing enzymatic activity, and inducing stomatal closure. Despite this, plants possess morphological, physiological, biochemical, and molecular defense mechanisms that vary among species, indicating a strong genetic influence on stress tolerance [6]. Okunlala et al. (2017) [5] reported that drought stress reduced relative water content, total chlorophyll, and carotenoid levels in chili plants at different growth stages. Chili is particularly sensitive to drought due to its shallow root system, whereas deeper and stronger roots improve drought resilience [2][6]. Based on this background, the present study investigates the morphophysiological responses of four red chili (*Capsicum annuum*) varieties (Ciko, Lembang 1, Tanjung 2, and Lingga) under drought stress.

2 Method

2.1 Cultivation and drought stress

Seeds of four red chili varieties (Ciko, Tanjung 2, Lembang 1, and Lingga) were sown in trays containing Trubus planting media and watered daily. After 14 days after planting (DAP), seedlings were transplanted into polybags measuring 30 × 30 cm, each containing 2 kg of Trubus planting media. Following transplantation, plants were acclimated and maintained under standard cultural practices, including daily watering, for seven days. Drought stress was imposed by withholding water for 14 consecutive days, while control plants were irrigated daily. Environmental conditions during the experiment, including ambient temperature, relative humidity, and light intensity, were monitored.

2.2 Plant height measurement

Plant height was measured at the end of the drought stress treatment from the soil surface to the tip of the highest growing point using a ruler.

2.3 Root length measurement

Root length was determined at the end of the drought treatment. Roots were photographed and analyzed using ImageJ software to measure their length.

2.4 Relative Water Content (RWC)

RWC was measured using a modified version of the Barr and Weatherley method [12]. Three leaves per plant were sampled. Fresh weight (FW) was recorded, followed by soaking the leaves in distilled water for 24 hours to obtain the turgid weight (TW). Leaves were then oven-dried at 80°C for 48 hours to determine dry weight (DW). RWC was calculated using the formula:

$$\text{RCW}\ (\%) = \frac{\text{Wet Weight} - \text{Dry Weight}}{\text{Saturated Weight} - \text{Dry Weight}} \times 100\% \quad (1)$$

2.5 Chlorophyll content

The second and third fully expanded leaves were sampled. Leaf tissue (0.1 g) was homogenized in 10 mL of 80% acetone and incubated at room temperature for 12 hours. Chlorophyll a, chlorophyll b, and total chlorophyll concentrations were determined spectrophotometrically at 646 and 663 nm [3]. Total chlorophyll content was calculated as:

$$\text{Total chlorophyll} = 17.3\ (\text{Abs}_{646}) + 7.18\ (\text{Abs}_{663})\ \text{mg/L} \quad (2)$$

2.6 Carotenoid content test

Leaf samples (0.1 g) were homogenized in 10 mL of cold 80% acetone and allowed to extract for 12 hours. Absorbance was measured at 480, 645, and 663 nm using a spectrophotometer. Total carotenoid content (µmol/g fresh weight) was calculated using the formula [3]:

$$\text{Totalcarotenoids}(\mu\text{mol/g}) = \frac{(\text{A480} + 0{,}114 \times \text{A663} - 0{,}638 \times \text{A645}) \times \text{V}.10^{3}}{112{,}5 \times \text{W}} \quad (3)$$

2.7 Research design and data analysis

The experiment was conducted using a completely randomized design (CRD) with a single factor, namely chili variety (Ciko, Tanjung 2, Lembang 1, and Lingga), with five replications. Physiological data were analyzed quantitatively using one-way ANOVA. When significant differences were detected ($p < 0.05$), Tukey's post-hoc test was performed to determine which varieties differed significantly. All statistical analyses were conducted at a 95% confidence level ($\alpha = 0.05$) using Minitab 18 software.

3 Result and Discussion

3.1 Morphological response of chili varieties to drought stress

3.1.1 Effect of drought stress on plant height

Plant height is a key morphological parameter used to assess the response of chili varieties to drought stress. Previous studies have highlighted plant height as a critical agronomic trait reflecting plant adaptation under water-limited conditions [7]. Statistical analysis in the present study demonstrated that drought stress significantly influenced the plant height of four chili varieties (Ciko, Tanjung 2, Lembang 1, and Lingga) ($p < 0.05$). The average height of all tested varieties was reduced under drought conditions compared to the control group (**Fig. 1**).

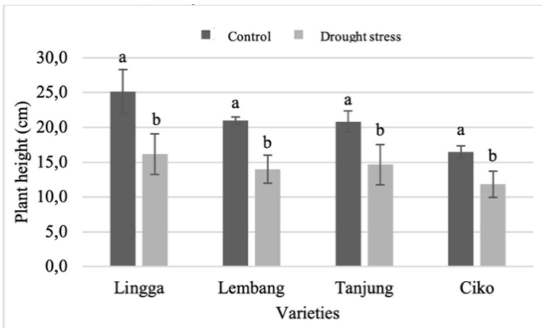

Fig. 1. Average plant height of selected *Capsicum annuum* varieties under drought stress.

Under control conditions, Lingga showed the greatest height (25.2 ± 3.2 cm), followed by Lembang 1 (21 ± 0.5 cm), Tanjung 2 (20.8 ± 1.5 cm), and Ciko (16.5 ± 0.9 cm). Under drought stress, height decreased in all varieties, with Lingga remaining the tallest (16.2 ± 2.9 cm) and Ciko the shortest (11.8 ± 1.9 cm). These findings indicate that drought reduced vegetative growth across all varieties, consistent with growth declines previously observed in tomato and rice under water-limited conditions [8].

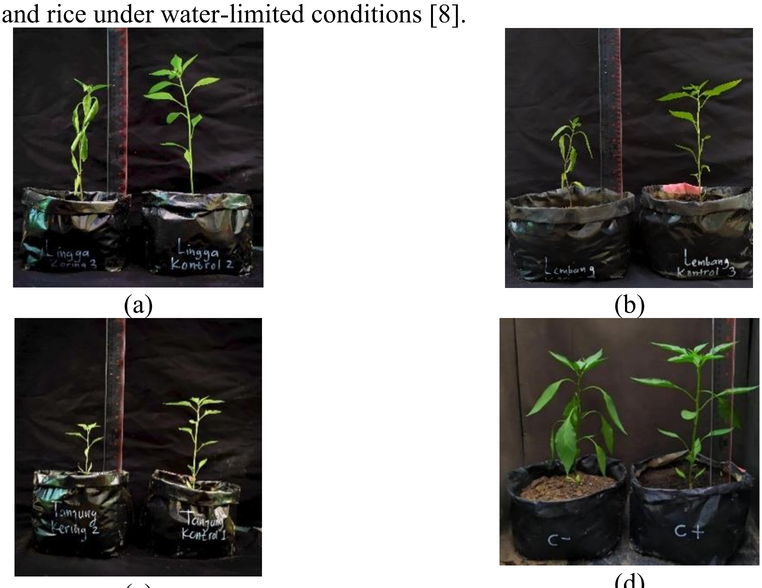

Fig. 2. Plant height of control (right) and drought-stressed (left) *Capsicum annuum* varieties : (a) Lingga, (b) Lembang 1, (c) Tanjung 2, (d) Ciko

The percentage reduction in plant height under drought stress varied among the four *Capsicum annuum* varieties. Lingga showed the greatest decrease (35.76%), while Ciko exhibited the smallest (28.28%). Lembang 1 and Tanjung 2 experienced reductions of 33.33% and 29.6%, respectively. These differences likely reflect the polygenic nature of drought tolerance [2], which involves interactions among molecular, biochemical, and physiological processes that influence growth in each variety [8]. During the vegetative phase, drought limits growth by reducing cell division and elongation [2], processes that require adequate turgor pressure [5]. Reduced water availability lowers turgor, resulting in suboptimal elongation and decreased plant height.

3.1.2 Effect of drought stress on root length

The second morphological parameter evaluated under drought stress was root length, an important trait that determines the plant's ability to access soil water [9]. Statistical analysis showed that drought stress did not significantly affect the root length of the four varieties (Ciko, Tanjung 2, Lembang 1, and Lingga) ($p > 0.05$). However, the mean root length under drought stress was slightly higher than that of the control group (**Fig. 2**).

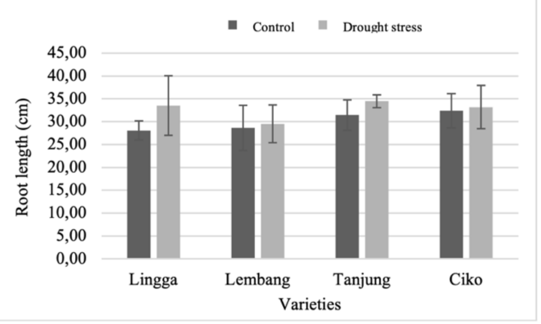

Fig. 3. Average root length of selected *Capsicum annuum* varieties under drought stress

Under control conditions, root length ranged from 28.09 ± 2.1 cm in Lingga to 32.38 ± 3.7 cm in Ciko. Following exposure to drought stress, all varieties showed a slight increase in root length, with Lingga reaching 33.55 ± 2.9 cm, Lembang 1 at 29.54 ± 4.2 cm, Tanjung 2 at 34.49 ± 1.4 cm, and Ciko at 33.20 ± 4.8 cm. These results suggest that, unlike plant height, root elongation in these varieties may not be adversely affected by drought stress and may even exhibit a compensatory growth response.

Drought stress in *C. annuum* increased root length compared to unstressed plants, a response also reported in *Nerium oleander*, *Opuntia ficus-indica*, *Opuntia robusta*, and roses (*Rosa multiflora* and *Rosa odorata*) [10]. The magnitude of this increase differed among varieties: Lingga showed the highest increase (19.44%) and Ciko the lowest (2.53%), while Lembang 1 and Tanjung 2 had intermediate increases of 3.07% and 9.74%. These patterns were opposite those observed for plant height, where Lingga had the greatest reduction and Ciko the least. Under drought, plants typically channel more assimilates to root development while shoot growth declines, enabling deeper soil penetration for improved water and nutrient uptake [10,11]. This adaptive response, known as xerotropism, reflects downward root growth under limited water availability [12] and is regulated by auxin biosynthesis, transport, and signaling [13].

3.2 Physiological response of chili varieties to drought stress

3.2.1 Effect of drought stress on Relative Water Content (RWC)

Relative Water Content (RWC) is a key physiological parameter used to assess the response of chili varieties to drought stress. RWC provides an estimate of plant water status, reflecting adjustments in leaf water potential and osmotic balance under stress conditions [10]. Statistical analysis indicated that drought stress significantly affected the RWC of the four chili varieties tested (Ciko, Tanjung 2, Lembang 1, and Lingga) ($p < 0.05$). Compared to the control, all varieties exhibited a decrease in mean RWC (**Fig. 4**).

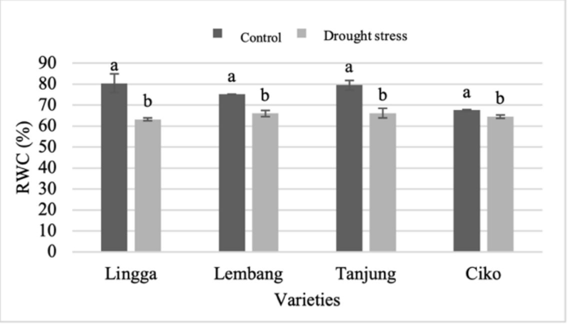

Fig. 4. Average RWC of selected *Capsicum annuum* varieties under drought stress

Drought stress significantly reduced relative water content (RWC) in all four *Capsicum annuum* varieties ($p < 0.05$). Under control conditions, RWC ranged from 68 ± 0.32% in Ciko to 80 ± 4.46% in Lingga, and decreased under drought to 63 ± 0.69% in Lingga, 66 ± 1.50% in Lembang 1, 66 ± 2.32% in Tanjung 2, and 64 ± 0.82% in Ciko. These findings indicate reduced water retention capacity under drought, reflecting the physiological impact of limited water availability.

The greatest RWC reduction occurred in Lingga (21.25%), while the smallest was observed in Ciko (5.88%), with Lembang 1 and Tanjung 2 showing intermediate decreases of 12% and 16%. These trends parallel the reductions in plant height. Loss of cellular water under drought reduces turgor pressure, inhibiting cell division and elongation [12], and may alter membrane permeability [14]. Variations in RWC reflect genotypic differences affecting water absorption and conservation. Under low soil moisture, plants reduce transpiration through stomatal closure induced by abscisic acid (ABA) signaling, which lowers CO_2 uptake, photosynthesis, and growth. Stomatal movement is further influenced by cellular water status, as reduced water availability decreases solute levels in guard cells, causing stomata to close [15].

3.2.2 Effect of drought stress on total chlorophyll content

Total chlorophyll content was assessed as a physiological response parameter in several *Capsicum annuum* varieties, as chlorophyll serves as an indicator of photochemical activity and plant tolerance to environmental stress, including drought [3]. Statistical analysis showed that drought stress significantly reduced total chlorophyll content in all four varieties (Ciko, Tanjung 2, Lembang 1, and Lingga) ($p < 0.05$), with mean values lower than those of the control group (**Fig. 5**).

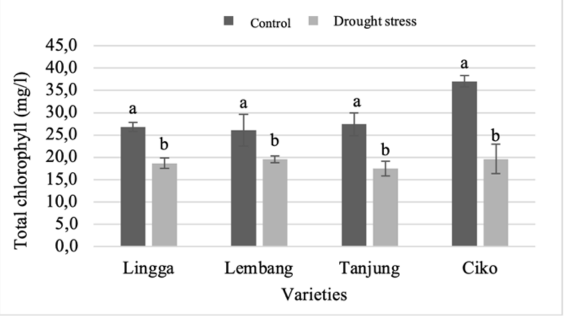

Fig. 5. Average total chlorophyll content of selected *Capsicum annuum* varieties under drought stress

Under control conditions, chlorophyll content ranged from 26.1 ± 3.6 in Lembang 1 to 37.0 ± 1.3 in Ciko. Under drought stress, chlorophyll content decreased in all varieties, with Lingga at 18.7 ± 1.2, Lembang 1 at 19.6 ± 0.7, Tanjung 2 at 17.5 ± 1.6, and Ciko at 19.7 ±

3.3. These results show that drought negatively affects photosynthetic pigment composition, which may reduce photochemical efficiency and overall plant growth.

The reduction in total chlorophyll content varied among the varieties, with the greatest decrease in Ciko (46.75%) and the smallest in Lembang 1 (24.90%), while Lingga and Tanjung 2 showed intermediate reductions of 43.31% and 36.13%. A decline in chlorophyll indicates environmental stress [8], as drought can reduce chlorophyll through chloroplast damage or inhibition of its biosynthesis [3]. Excess reactive oxygen species (ROS) may further induce oxidative injury, causing lipid peroxidation, damage to proteins and nucleic acids, enzyme inhibition, and programmed cell death [7,8,12]. Drought-induced lipid peroxidation can also alter chloroplast ultrastructure, including thylakoid swelling and grana loss [13], and inhibit multiple steps of chlorophyll biosynthesis while limiting Mg and Fe uptake [14]. Overall, reduced chlorophyll under drought represents an adaptive mechanism to limit excess energy absorption and prevent photodamage [11,13].

3.2.3 Effect of drought stress on carotenoid content

Carotenoid content was evaluated as a physiological response in several *Capsicum annuum* varieties, as these pigments contribute to stress tolerance [5]. Statistical analysis showed that drought stress did not significantly affect carotenoid levels in Ciko, Tanjung 2, Lembang 1, and Lingga ($p > 0.05$), consistent with reports that water deficit may variably influence carotenoid synthesis [7]. Nonetheless, mean carotenoid content under drought was lower in all varieties compared to the control (**Fig. 6**).

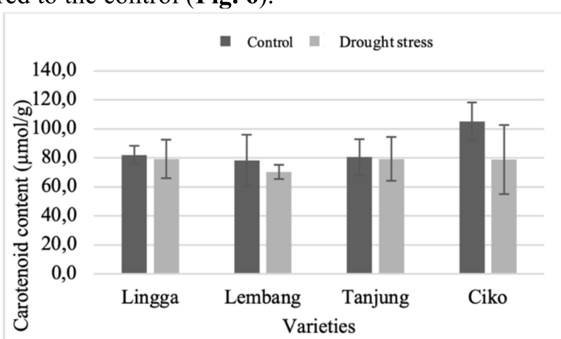

Fig. 6. Average carotenoid content of selected *Capsicum annuum* varieties under drought stress.

Under control conditions, carotenoid content ranged from 78.1 ± 17.7 in Lembang 1 to 105.2 ± 13 in Ciko. Under drought stress, levels decreased slightly in all varieties, with Lingga at 79.2 ± 13.3, Lembang 1 at 70.3 ± 4.8, Tanjung 2 at 79.2 ± 15.1, and Ciko at 78.9 ± 23.7. These results indicate that carotenoid accumulation remains relatively stable under water-limited conditions, reflecting their protective role against oxidative stress.

The magnitude of reduction varied among varieties, with the largest decrease in Ciko (24.80%) and the smallest in Tanjung 2 (1.73%), while Lembang 1 and Lingga showed intermediate reductions of 9.98% and 3.41%. These findings align with reports that drought during the vegetative phase reduces carotenoid levels in chili plants [5], as carotenoids act as antioxidants that protect the photosynthetic apparatus from light-induced and ROS-mediated damage. In contrast, carotenoid synthesis typically increases during the generative phase, indicating greater drought tolerance at later developmental stages [5,12,15].

4 Conclusion

Drought stress significantly influenced the morphological and physiological traits of the four *Capsicum annuum* varieties. Plant height and relative water content decreased, especially in Lingga, while root length showed a slight increase as an adaptive strategy to enhance water uptake. Total chlorophyll content declined in all varieties, whereas carotenoid levels remained relatively stable, reflecting their role in protecting against oxidative stress. These results demonstrate clear genotypic variation in drought tolerance. Future research should investigate the underlying genetic and molecular mechanisms and validate these drought-tolerant traits under field conditions to support the development of resilient *C. annuum* cultivars.

Reference

1. Phimchan, Paongpetch & Suchila Techawongstien. Impact of drought stress on the accumulation of capsaicinoids in Capsicum Cultivars with different initial capsaicinoid levels. HortScience. **47**, 9, 1204-1209 (2012).
2. Hussain, H.A., Hussain, S., Khaliq A, Ashraf, U., Anjum, S.A., Men, S. & Wang, L. Chilling and drought stresses in crop plants: implications, cross talk, and potential management opportunities. Front Plant Sci. **9** (2018).
3. Jadid N., Maziyah R., Nurcahyani D.D., Mubarokah N.R. Growth and physiological responses of some *Capsicum frutescens* varieties to copper stress. AIP Conf. Proc. **1854**, 020018-1–020018-7 (2016).
4. Lipiec J., Doussan C., Nosalewicz A., Kondracka K. (2013). Effect of drought and heat stresses on plant growth and yield: a review. Int. Agrophys, **27**, 463–477 2013.
5. Okunlolaa G. O., Olusanya, A.O., Richard, O.A., Akash, T. & Adekunle, A.A. Physiological response of the three most cultivated pepper species (*Capsicum* spp.) in Africa to drought stress imposed at three stages of growth and development. Scientia Horticulturae. **224**, 198-205 2017.
6. Andriyani, & Jadid, N. Genetic diversity and morphological responses of *Capsicum annuum* varieties under aluminum stress. Biodiversitas. **22**, 5, 2576–2582
7. Huber, A.E. & Bauerle, T.L. Long-distance plant signaling pathways in response to multiple stressors: the gap in knowledge. Journal of Experimental Botany. **67**, 7, 2063–2079 (2016).
8. Mafakheri, A., Siosemardeh, A., Bahramnejad1, B., Struik, P.C. & Sohrabi, Y. Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. Australian Journal of Crop Science, **4**, 8, 580-585 (2010).
9. Ahmadikhah, A. & Marufinia, A. Effect of reduced plant height on drought tolerance in rice. *3* Biotech, 6, 220-221 (2016).
10. Uppuluri, L.S. & Krishna M.S.R. Screening of chilli genotypes for drought tolerance. New Horizons in Biotechnology. (Eds. Viswanath B and Indravathi G). (Paramount Publishing House, 2015).
11. Kumar, R.M.K., Berwal, P.L. & Saroj. Morphological, physiological, biochemical and molecular facet of drought stress in horticultural crops. International Journal of Bio-resource and Stress Managemen. **10**, 5, 545-560 (2019).
12. Nisa, C., & Jadid, N. Exogenous acetic acid pre-treatment increases drought tolerance of two Indonesian foxtail millet (*Setaria italica*) accessions. Biodiversitas, **22**, 4, 2117–2124 (2021).
13. Feng, W., Lindner, H., Robbins, N.E. & Dinneny, J.R. Growing out of stress : the role of cell-and organ-scale growth control in plant water-stress responses. Plant Cell, 28, 1769-1782 (2016).
14. Lynch, J.P. Rightsizing root phenotypes for drought resistance. J. Exp. Bot. **69**, 3279–3292 (2018).
15. Reyes A., Oscar, A., & Javier, A. Effect of irrigation suspension on the growth, water state and production of spinach (*Spinacia oleracea* L.) plants. Agronomía Colombiana. **36**, 2, 120-125 (2018).