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Review paper

POSSIBILITIES OF CABBAGE PRODUCTION UNDER CLIMATIC CHANGES

Janko F. Červenski[1*], Vlajić A. Slobodan[1], Boris D. Adamović[2], Đorđe S. Vojnović[2] and Srđan D. Zec[1]

[1]Institute of Field and Vegetable Crops,
National Institute of the Republic of Serbia,
Maksima Gorkog 30, 21000 Novi Sad, Serbia
[2]University of Novi Sad, Faculty of Agriculture,
Trg Dositeja Obradovića 8, 21000 Novi Sad, Serbia

Abstract: Cabbage growth and development require temperatures between 15 and 18ºC. However, for most of the growing season, cabbage is exposed to temperatures above 20ºC. To obtain the highest possible prices on farmer's markets, cabbage producers start cabbage planting at the earliest possible dates (early or late autumn). Cabbage growth is "pushed forward" by more abundant irrigation, planting density, cultivation, and protection, to form a marketable (technologically mature) head in the shortest possible time and achieve the highest possible profit on the market. To improve the efficiency of water use and adapt cabbage to warmer and drier conditions, it is recommended to use modified production systems, with an emphasis on postponing the date of sowing or planting to mitigate the effects of temperature increase and drought during cabbage production. This paper aims to point out the effects of temperature and water stress and to provide solutions that can be practically applied to mitigate the negative impacts of these stress factors on cabbage production. Priority should be given to the development of production systems that improve the efficiency of water use adapted to the conditions of hot and dry weather. Irrigation of cabbage should be organised as drip irrigation, as this is a more rational system, with the possibility of comparative feeding and protection.

Key words: temperature stress, water stress, cabbage, irrigation, mulching.

Introduction

The geographic position of Serbia allows for a year-round open-field or greenhouse production of cabbage. The production of early cabbage starts in January and February, while late cabbage is harvested at the end of November or

[*]Corresponding author: e-mail: janko.cervenski@ifvcns.ns.ac.rs

even later, until the occurrence of severe frosts. Cabbage is produced all year round, as early cabbage for fresh consumption and as late cabbage for preservation. The cultivation of cabbage is most often defined by the way it is used, i.e. fresh, cooked or pickled. The specificities of the production methods mentioned are closely related to the weather conditions in the part of the year when the production takes place. Although it is adapted to different climatic and soil conditions, cabbage is better suited to cooler and wetter growing areas (Osher et al., 2018). This rule also applies to parts of the year with cooler temperatures, to which cabbage responds very well at all stages of development (Červenski et al., 2022).

Environmental factors have been changing more rapidly, affecting vegetable production and quality. Reduced vegetable production is likely to be caused by a shortened production period, which will negatively affect growth and development, especially under conditions of heat stress and reduced water availability. Climate change causes additional uncertainties and risks, increasingly limiting production, which leads to an increase in the price of vegetables. These changes encourage the spread of pathogens and the development of new pest species and pathogen strains (Malhotra and Srivastva, 2014). The challenges to be faced in the coming years are sustainability and competitiveness, achieving targeted production that can meet the growing demands despite the reduction in arable land and water shortages. New models are needed in order to improve the production of vegetables, with special interventions in certain areas that require experience, knowledge, and the application of new techniques and technologies (Malhotra and Srivastva, 2015).

Cabbage growth and development require temperatures between 15 and 18ºC (Hara and Sonoda, 1982; Criddle et al., 1997; Žnidarčič et al., 2007; Kołota and Chohura, 2015; Lešić et al., 2016; Červenski and Medić-Pap, 2018). However, for the most part of the growing season, cabbage is exposed to temperatures above 20ºC. In the Republic of Serbia, such temperatures occur from the beginning of April to the end of September. In Serbia, the production of early cabbage in the open field, the production of summer cabbage, and the first stage of the autumn cabbage production take place during these months. So as to obtain the highest possible prices on the farmer's markets, cabbage producers start planting cabbage at the earliest possible dates (early or late autumn). Cabbage growth is "pushed forward" by more abundant irrigation, planting density, cultivation and protection, in order to form a marketable (technologically mature) head in the shortest possible time and achieve the highest possible profit on the market.

The aim of this paper was to point out the effects of temperature and water stress and to provide solutions that can be practically applied in order to mitigate the negative impacts of these stress factors on cabbage production.

The area under cabbage cultivation in Serbia declined steadily from 2010 to 2023. In the observed period, cabbage yields mostly increased (Table 1), possibly due to the application of improved cultivation practices, such as the selection of high-yielding hybrids, sowing/planting a larger number of plants per unit area (denser planting), irrigation, control of weeds, disease-causing and harmful insects.

Table 1. Cabbage production areas (ha) and yield (t/ha) in Serbia from 2010 to 2023 (https://www.stat.gov.rs).

Year	Production area (ha)	Yield (t/ha)	Year	Production area (ha)	Yield (t/ha)
2010	20891	16.1	2017	10213	25.7
2011	20581	15.3	2018	8251	25.4
2012	20441	12.2	2019	7957	22.4
2013	19422	14.3	2020	7547	23.8
2014	11116	23.5	2021	7513	24.7
2015	12061	27.9	2022	7335	22.6
2016	10804	26.8	2023	7111	22.3

Thermal and precipitation characteristics of the vegetation period (April–September) in the Republic of Serbia from 2010 to 2024

For a better understanding of the effects of temperature and water stress on the production of cabbage, the thermal and precipitation characteristics of the growing season (April–September) from 2010 to 2024 in the Republic of Serbia are presented in this paper.

The number of days with a maximum air temperature > 20ºC (Tmax >20ºC) in the growing season (April–September) in the period 2010–2024 ranged between 131 (2019) and 169 days (2018) (Figure 1).

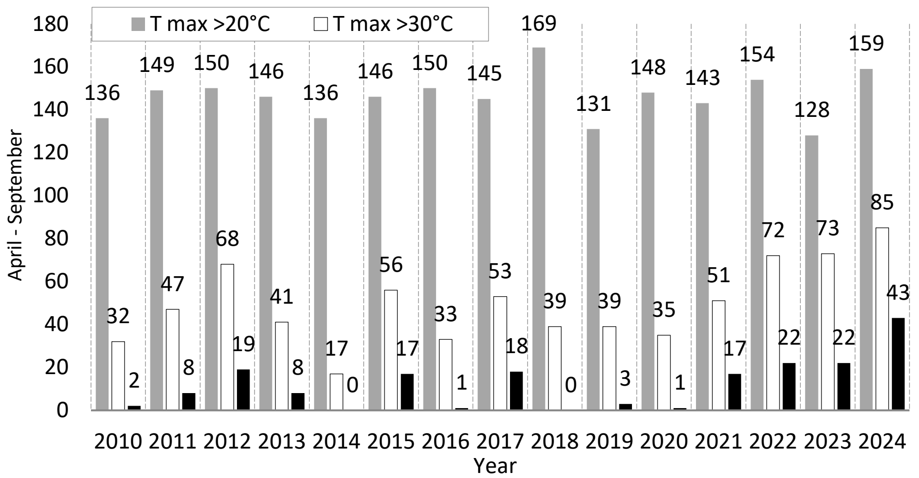

Figure 1. Number of days with T-max>20ºC; T-max>30ºC T-max>35ºC during the vegetation period (April–September) in 2010–2024 in Serbia. (https://www.hidmet.gov.rs/)

The number of days with a maximum air temperature > 30ºC (Tmax >30ºC or summer days) in the growing season (April–September) in the period 2010–2024, ranged between 17 (2014) and 85 days (2024) (Figure 1).

The number of days with a maximum air temperature > 35ºC (Tmax >35ºC or tropical days) in the growing season (April–September) in the period 2010–2024 ranged between 0 (2014 and 2018) and 43 days (2024) (Figure 1).

In July and August, tropical temperatures were recorded at night (morning temperatures were above 20°C), 26ºC in July 2023, as well as 17 days in 2024 (https://www.hidmet.gov.rs/).

The number of rainy days during the vegetation period (April–September) in 2010–2024 varied from 29 (2023) to 70 (2014) (Figure 2).

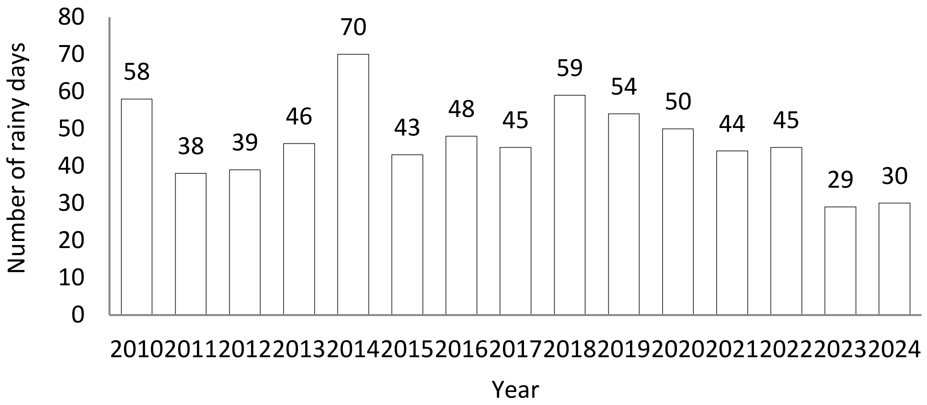

Figure 2. Number of rainy days during the vegetation period (April–September) in 2010–2024 in Serbia. (https://www.hidmet.gov.rs/)

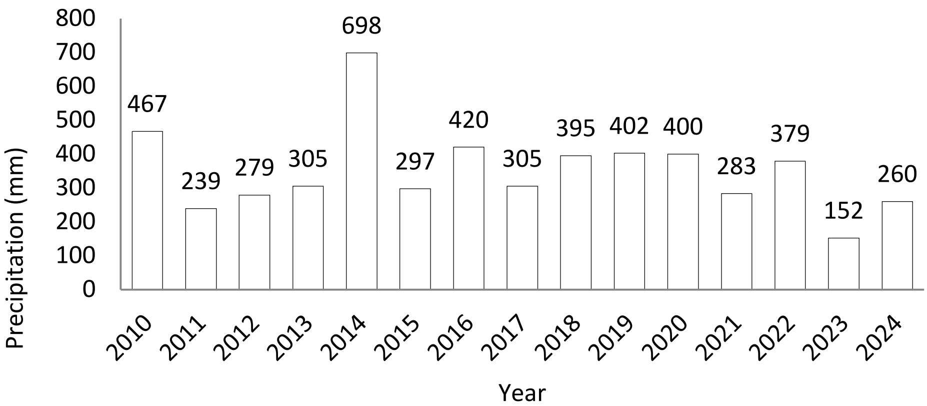

Figure 3. Precipitation in mm during vegetation (April–September) in 2010–2024 in Serbia. (https://www.hidmet.gov.rs/)

Precipitation in mm during the vegetation period (April–September) in 2010–2024 in Serbia varied from 152 mm (2023) to 698 mm (2014) (Figure 3).

Possibilities of mitigating the negative impacts of temperature stress on cabbage production

When producing early cabbage in the open field or in the greenhouse, it is necessary to react adequately and timely so as to reduce the impacts of low temperatures. Low temperatures during spring can extend the planting time of early cabbage and have a negative impact on early cabbage sown or planted in an unheated greenhouse or in the open field, which can result in partial damage to individual plants or complete failure of production. In the winter/spring period, low temperatures in the range of 0°C and even below -10°C, with weaker or stronger frosts, are possible. Under the conditions of low temperatures, the plant primarily defends itself by closing the stomata, which reduces the intensity of one of the basic physiological processes – photosynthesis. In order to strengthen the cabbage seedling as much as possible, it is necessary to gradually expose it to external weather conditions, unpredictable situations and temperature fluctuations (Červenski and Medić-Pap, 2018; Červenski et al., 2022).

Early cabbage production in the greenhouse takes place in tunnels without additional heating at a height of 1.8–2.5 m (Ilin et al., 2017), and is often accompanied by the use of several polythene sheets to prevent vernalisation of the early cabbage plants due to prolonged exposure to low temperatures.

At a temperature of 4–5ºC, the vegetative cabbage head can undergo vernalisation, while the most intensive processes occur at a temperature of 5 to 6ºC. This is an undesirable phenomenon in early production. Longer exposure to low temperatures of 5 to 7ºC in more sensitive cabbage varieties and hybrids leads to vernalisation and flowering. Length of the vernalisation stage ranges from 30 to 70 days (Amasino, 2004). With a day length of 12 hours and temperature conditions of 6°C, vernalisation lasts about 7 weeks. In early spring production, cabbage seedlings can vernalise in 12–14 days during periods of low temperatures (Adžić et al., 2012; Červenski and Medić-Pap, 2018).

On the one hand, quality polyethylene films in early production preferably have a high surface tension of the inner layer, so that the hanging drops do not reflect a significant amount of direct sunlight and thus reduce the length and intensity of photosynthetic activity. On the other hand, direct sunlight transports more heat than diffused sunlight and the temperature under such foils is significantly higher. If such foils also contain a supplementary thermo-protective barrier against the radiation of heat accumulated in the soil and in the young plants during the sunny days, then in addition to exceptional earliness, larger and more beautiful heads, higher yields and significantly higher profits can be expected (Momirović, 2004, Kim et al., 2022).

The maximum film thickness acceptable from the point of view of thermal and mechanical properties depends on the width of the film, which is about 80 microns for tunnels covered with an 8 m wide film. Tests have shown that the non-drip, thermo-protective foil of 80 microns ensures a temperature higher by 4–5ºC after weaker morning radiation frosts compared to the standard foil of 160 microns, which is mainly used by our manufacturers (Červenski and Medić-Pap, 2018).

Mulching is also a key factor for the successful cabbage production (Ilić and Milenković, 2022). Natural mulch contributes organic matter to the soil, whereas synthetic mulch raises soil temperature, retains moisture, and minimises weed competition. The impact of seeding varies with the growing season. Using black polyethylene film to cover the soil is advisable when the spring is cold and wet, but its benefits may be diminished at higher temperatures (Adamović et al., 2023). Black polyethylene mulch absorbs heat from solar radiation, raising soil temperature, which helps boost cabbage production, particularly during the winter season (Farjana et al., 2019; Adamović, 2020; Ponjičan et al., 2021).

Production of cabbage in greenhouses during the winter-spring period requires additional heating and the use of double covering foils and agro-textiles inside the greenhouse. Fleece films, categorised as non-woven agro-textiles, are made with specific technology from UV-stabilised polypropylene and serve as a thermal barrier that mitigates temperature extremes in the crops. They do not contain any chemical agents, but the fibres are connected by a specific thermal process. They have high light transparency and permeability to water and air, and are applied by directly covering young, sprouted or transplanted plants (Khramov et al., 2022).

In cabbage production, they are used at low temperatures, rarely at extremely high temperatures, or when additional protection against harmful insects, vectors, dangerous viral diseases, or in the organic growing system is required. These light thermal protection barriers usually weigh 17–60 g/m^2, but when they are slightly thicker, they provide an ideal environment for accelerating the growth of cultivated cabbage, ensuring earlier arrival and higher yields, and protecting crops in the coldest periods. They are especially effective during light radiation morning frosts when, thanks to the retention of long-wave thermal radiation, the temperature of the ground layer is 4 to 5ºC higher. The effect of previously accumulated heat in the soil and in the plants does not last longer than a few days if very cold weather accompanied by weak daylight lasts longer. Therefore, the best effect of covering the plants directly with agro-textiles is related to transitional seasons. In addition, it is notable that due to the high permeability of agro-textiles, we can easily irrigate the cabbage using micro-irrigation without removing the foil beforehand. However, the application of pesticides or water-soluble fertilisers is not allowed, because it can drastically reduce the duration that extends over several seasons of vegetable growing (Ilin et al., 2017; Stanciu, 2023). In the study by Stanciu (2023), covering cabbage with agrotextile in early production in the greenhouse and in the open field resulted in a 4–7-day earlier harvest as well as a higher rosette diameter, plant height, number of leaves in the rosette, head weight, leaf weight.

For cabbage production in greenhouses during spring and autumn, the average daily temperature should range between 15 and 25°C, i.e. 10 and 30°C (Xianbing et al., 2020). In warmer years, plastic mulching films can increase the soil temperature around the root system, which can negatively impact cabbage growth and yield. Therefore, they should be avoided in areas with high levels of solar radiation (Djigma and Diemkouma, 1986, Díaz-Pérez and Batal, 2002, Adamović et al., 2023). Some authors (Hou et al., 2010) recommend removing plastic films at a certain stage of plant development.

July and August are usually the hottest months of the year. These two summer months are characterised by temperature stress with high temperatures over 32–33°C, and often 34–35°C. Chang et al. (2016) reported that daily temperatures exceeding 30°C during summer reduce the yield and quality of cabbage. A larger number of leaves and a larger leaf area were recorded when growing cabbage at 20°C, compared to 25°C, while no significant differences were observed between 20 and 22.5°C (Suh et al., 2012). The same authors state that the decrease in yield under the influence of a temperature of 22.5°C amounts to 4%, while the decrease in yield under the influence of a temperature of 25°C amounts to 15%.

Optimum temperatures for cabbage are 20°C during the day and 15°C at night (Kalloo and Bergh, 2012). The occurrence of high temperatures also represents stress. Temperature stress can have a negative effect on the final stage of the vegetation period of summer cabbage and the initial phase of the vegetation period of late or autumn cabbage intended for preservation. Extended periods of higher temperatures lead to an increased number of plants that do not form heads, premature flowering, smaller heads (Kalloo and Berg, 2012), firmer leaf texture, curling, scalding, and damage to the leaves of the rosette and heads, as well as slower growth (Yue et al., 2021), loose heads, and the appearance of multiple smaller heads on a single plant (Figures 1 and 2).

Due to the high temperatures caused by climate change, plants adjust their metabolism, which can affect their nutritional value. High temperatures trigger physiological and biochemical changes in plants that influence their nutritional potential (Gmižić et al., 2023). The same authors note that high temperatures significantly increased the content of total phenols, soluble sugars, carotenoids, potassium, sodium, and antioxidant capacity as measured by the ABTS and FRAP assays.

In order to maximise the profitability of production, producers should know the cultivated cabbage variety/hybrid and, above all, its vegetation period. In spring production, knowing the vegetation period of the cultivated cabbage variety/hybrid can ensure that negative effects of high temperature stress, which is more common in June and July, are avoided. Stanciu (2023) emphasises the importance of hybrid selection for extra-early cabbage production.

Figure 4. Loose head.
(Adamović B., 2024)

Figure 5. Multiple heads of cabbage.
(Adamović B., 2024)

Knowing the length of late cabbage vegetation from the autumn production, the aforementioned practices can be organised with a time shift in planting dates towards August or September. Temperatures are more optimal for the production of autumn cabbage during September, October and November. With this system of organising cabbage production, the priority to bringing fresh autumn cabbage to the market, when the prices are at their highest, is lost. However, producers get a safer production of better-quality cabbage, which should be the main goal of any production.

One way to maximally compensate for the impacts of high temperatures on cabbage production is to cultivate locally grown cabbage varieties. Cabbage varieties and populations that originated or became domesticated in a particular area should be cultivated as much as possible for several reasons. These varieties are well adapted to local climatic conditions, tolerate new climatic changes well, often have better quality (sugar content and lower leaf thickness) than other cultivated cabbage hybrids, and are part of the culinary tradition in a particular area.

Possibilities of mitigating the negative impacts of water stress on cabbage production

Cabbage requires high soil moisture throughout the growing season, which makes it a hydrophilic plant. Shock and Wang (2011) state that the plant species *Brassica oleracea* is one of the most sensitive to soil water deficiency, while Bute et al. (2021) claim that cabbage is moderately sensitive to water stress. If soil moisture exceeds desirable levels, cabbage will consume it inefficiently and uneconomically (Červenski and Takač, 2012). Cabbage forms a large above-ground mass with large leaves and has a shallow but extensive root system, with a depth of up to 30 cm, where the greatest root mass is concentrated in the top 10-cm layer (Yamamoto et al., 2015). The root surface area through which it absorbs water and nutrients is up to 25 cm^2 (Cobos-Tores et al., 2021). The visible leaf area at the beginning of head formation ranges from 0.59 to 0.91 m^2, and during the head formation stage, it ranges from 0.57 to 0.85 m^2 (Lüling et al., 2022), which affects the high transpiration and water requirements, while the cabbage leaf area index is around 3.96. The high leaf area index and the high transpiration lead to rapid soil drying (Seidel et al., 2017).

The accurate estimation of crop water requirements is an important prerequisite for high yields and crop productivity (Seidel et al., 2017). Water requirements are also determined by the growth phase, and the greatest is during the seedling stage, intensive growth of the rosette leaves and head formation (Karagić, 1998). In addition, water requirements are determined by the time and location of crop growth. The water requirements are the highest during the hot days of July and August, and higher than during the head growth at lower temperatures and higher humidity, which reduces transpiration and evaporation of water from the soil (Bošnjak, 2003). Similarly, Seidel et al. (2017) state for the agroecological conditions in Germany that plants expirience drought stress for up to 62 days after transplanting, and that rainfall or irrigation in later stages can compensate for the stress caused by early water deficiency.

Multi-year research by Domuta et al. (2017) shows that autumn cabbage requires a substantial amount of water. This is supported by Büyükcangaz (2018), who states that cabbage requires 380 to 500 mm of water depending on the climate and length of vegetation. Domuta et al. (2017) found that irrigation significantly increased the average cabbage yield by 153%.

It is also important to take into account precipitation throughout the entire growing season and the climate of the region where cabbage is grown, as well as to ensure critical irrigation stages during the 6–7-leaf stage and the beginning of head formation are not missed (Bute et al., 2021). The absence of irrigation during the head formation stage reduces head mass by more than 50%, leading to unacceptable market losses (Radovich et al., 2004). The same authors note that, in addition to lower yields, the value of the crop also decreases due to deviations in the shape and size of the heads.

Lower soil moisture slows down the formation of heads, which remain small and soft, while irrigation during head development results in larger and heavier heads, with a lower dry matter content (Radovich et al., 2005). Cabbage is sensitive to changes in soil moisture, especially in the stage of head formation and technological ripening. A water deficit 3 to 4 weeks before harvest lowers yield and quality. Low soil moisture stops the growth, while the leaves and heads are small and loose. If drought stress occurs in the earlier stages of plant development, it slows down the growth of the above-ground biomass, resulting in reduced plant height and smaller leaf area (Seidel et al., 2017). On the other hand, excessive humidity during this period can cause cracking in the heads. This occurs when the soil is dry for a prolonged period and when rewetting occurs through precipitation or watering (Červenski and Medić-Pap, 2018).

Irrigation and watering norms depend primarily on weather conditions and the amount and distribution of precipitation. Irrigation norms, i.e. the amount of water applied expressed in mm or litres, range from 3 to 8 or even more. For every 5 mm of natural rainfall, irrigation should be postponed by one day and conducted at every 6 to 8 days with about 30 mm of water (Dragović et al., 2006).

A decrease in soil moisture leads to an increase in soil temperature, which is another key factor affecting cabbage growth. Hamad et al. (2022) indicate that cabbage growers frequently apply high amounts of nutrients and water to increase yields, while Bute et al. (2021) state that excessive water usage become a standard practise in order to achieve higher yields. Excessive and frequent irrigation can negatively affect yield, but not as much as insufficient irrigation (Cripps et al., 1982). In addition to increasing overall costs, excessive irrigation can lead to nitrogen leaching (Imtiyaz et al., 2000; Seidel et al., 2017).

Irrigation can be performed using sprinklers (Imtiyaz et al., 2000; Maršić et al., 2012; Seidel et al., 2017) or a drip irrigation system (Radovich et al., 2004; Žnidarčič et al., 2007; Maršić et al., 2012; Adamović et al., 2023). Sprinkler irrigation produces a favourable effect on the microclimate, lowering the temperature of the leaves by 7–12ºC compared to the air temperature. Additionally, sprinkler irrigation increases the relative humidity, which should range between 85% and 90% for cabbage (Bute et al., 2021). Subsurface drip irrigation is a more efficient method of water management compared to other irrigation techniques. It offers several benefits, including water conservation, easy fertigation, and reduced surface runoff and deep percolation (Hamad et al., 2022). The main advantage of the drip irrigation system is that it reduces the occurrence of unfavourable conditions (wetting of leaves and heads), so the intensity of pathogen infestation in cabbage is much lower compared to irrigation systems using artificial rain (Vlajić et al., 2017).

If the cabbage is produced during the dry season at temperatures above 30ºC (during July and August), irrigation should be carried out every 8–12 days with a water rate of 30–40 mm. Frequent watering (every 4–6 days) at high temperatures (above 30ºC) can contribute to the formation of loose cabbage heads, which reduces the market value of cabbage (Červenski et al., 2008; Červenski and Medić- Pap, 2018).

The main element of rational irrigation in cabbage production is the knowledge of the potential evapotranspiration, i.e., plant water requirements, or consumption of water that contributes to the highest yield of good quality (Karagić, 1998). Cabbage has a lower evapotranspiration than other vegetable crops, because its leaves are covered with a thin wax coating and have a lighter colour, but it has higher water requirements. Evapotranspiration depends on the environment, the amount and distribution of precipitation during the growing season and water requirements of the plant. All these parameters are significantly changed by postponing the date of planting. Cabbage evapotranspiration decreases with later planting due to changes in the environment, i.e., a decrease in the sum of temperatures at later planting dates (Karagić et al., 2001).

Conclusion

The weather conditions in Serbia are gradually exceeding the levels required for the production of cabbage. The effects of temperature and water stress on cabbage production are increasing. Average air temperatures are the highest in July and August, causing temperature and water stress, which increases the cost of production and affects the final price of technologically mature heads.

To improve the efficiency of water use and adapt cabbage to warmer and drier conditions, it is recommended to use modified production systems, with an emphasis on postponing the date of sowing or planting in order to mitigate the effects of temperature increase and drought during cabbage production.

The avoidance of temperature and water stress must be adjusted with the aim of achieving maximum quality / technological compaction of the head, and the time needed for obtaining the highest price on the market.

The development of production systems that improve the efficiency of water use adapted to the conditions of hot and dry weather should be prioritised. The irrigation of cabbage should be organised as drip irrigation, as this is a more rational system, with the possibility of comparative feeding and protection.

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References

Adamović, B. (2020). Effect of mulching and fertilizing on yield and quality of cabbage [In Serbian]. University of Novi Sad, Faculty of Agriculture.

Adamović, B., Cabilovski, R., Vojnović, Đ., & Ilin, Ž. (2023). Effect of mulching on nutrient uptake and efficiency of fertilizers in mid-early cabbage production. *Acta Scientiarum Polonorum Hortorum Cultus, 22* (3), 79-90. https://doi.org/10.24326/asphc.2023.4813

Adžić, S., Girek, Z., Pavlović, N., Zdravković, J., Cvikić, D., Pavlović, S., & Prodanović, S. (2012). Vernalization and seed yield of late head cabbage in different phases of rosette development by applying GA3 in vivo. In *Proceedings of VI International Symposium on Brassicas and XVIII Crucifer Genetics Workshop 1005,* (pp. 369-374). Catania, Italy. https://doi.org/10.17660/ActaHortic.2013.1005.43

Amasino, R. (2004). Vernalization, competence, and the epigenetic memory of winter. *The plant cell*, *16* (10), 2553-2559. https://doi.org/10.1105/tpc.104.161070

Bošnjak, Đ. (2003). *Navodnjavanje u bašti.* Novi Sad: Univerzitet u Novom Sadu, Poljoprivredni fakultet.

Bute, A., Iosob, G.A., Antal-Tremurici, A., Brezeanu, C., Brezeanu, P.M., Cristea, T.O., & Ambăruş, S. (2021). The most suitable irrigation methods in cabbage crops (Brassica oleracea L. var. capitata): a review. *Scientific Papers. Series B. Horticulture*, *65* (1), 399-405.

Büyükcangaz, H. (2018). Deficit Irrigation Effects on Cabbage (*Brassicaceae Oleracea* var. *capitata* L. Grandslam F1) Yield in Unheated Greenhouse Condition. TURJAF, 6 (9), 1251-1257. https://doi.org/10.24925/turjaf.v6i9.1251-1257.2025

Chang, K.Y., Lin, K.H., Lo, Y.H., & Lo, H.F. (2016). Physiology and proteomics of cabbage under heat and flooding stress. *Journal of Botanical Sciences, 5* (2), 44-53.

Cobos-Torres, J.C., Alvarez-Vera, M., & Flores-Vasquez, C. (2021). Measurement of cabbage (Brassica oleracea L.) root treated with beneficial microbial consortia through computer vision technology. *Applied Ecology & Environmental Research*, *19* (6), 4959-4975.

Criddle, R.S., Smith, B.N., & Hansen, L.D. (1997). A respiration based description of plant growth rate responses to temperature. *Planta*, *201*, 441-445. https://doi.org/10.1007/s004250050087

Cripps, J.E.L., George, P.R., & Oakley, A.E. (1982). Scheduling irrigation of cabbages using pan evaporation. *Irrigation Science*, *3*, 185-195.

Červenski, J., Takač, A., Bugarski, D., & Jovićević, D. (2008). Zašto se pojavljuje rastresitost glavice kod kupusa? *Zbornik Radova-A Periodical of Scientific Research on Field & Vegetable Crops*, *45* (2), 203-206.

Červenski, J., & Takač, A. (2012). Growing cabbage as a double crop. *Ratarstvo i povrtarstvo, 49 (1),* 75-79. http://dx.doi.org/10.5937/ratpov49-1228

Červenski, J., & Medić-Pap, S. (2018). *Proizvodnja kupusa*. Novi Sad: Institut za ratarstvo i povrtarstvo.

Červenski, J., Vlajić, S., Ignjatov, M., Tamindžić, G., & Zec, S. (2022). Agroclimatic conditions for cabbage production. *Ratarstvo i povrtarstvo*, *59* (2), 43-50. https://doi.org/10.5937/ratpov59-36772

Díaz-Pérez, J.C., & Batal, K.D. (2002). Colored plastic film mulches affect tomato growth and yield via changes in root-zone temperature. *Journal of the American Society for Horticultural Science*, *127* (1), 127-135.

Dygima, A. and Demkouma, D. (1986). Plastic mulch in dry tropical zones, Trials on vegetable crops in Burkina Faso. *Plasticulture 69* (1), 19-24.

Domuta, C.G., Peres, A.C., Brejea, R.P., Borza, I.M., Eugen, J.U.D.E., Köteles, N., & Cenusa, N. (2017). Irrigation, a Basic Technological Element, for Improving the Autumn Cabbage Yield in Crișurilor Plain, Western Romania. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *45* (2), 582-588. https://doi.org/10.15835/nbha45210774

Dragović, S., Maksimović, L., Radojević, V., Cicmil, M. (2006). *Navodnjavanje u biljnoj proizvodnji.* Partenon, Beograd.

Farjana, S., Islam, M. Ashraful & Haque, T. (2019). Effects of organic and inorganic fertilizers, and mulching on growth and yield of cabbage (Brassica oleracea var. capitata L.). *Journal of Horticulture and Postharvest Research*, *2* (Issue 2), 95-104. https://doi.org/10.22077/JHPR.2019.2119.1042

Gmižić, D., Pinterić, M., Lazarus, M., & Šola, I. (2023). High Growing Temperature Changes Nutritional Value of Broccoli (*Brassica oleracea). Foods* 12 (3), 582. https://doi.org/10.3390/foods12030582

Hamad, A.A.A., Wei, Q., Wan, L., Xu, J., Hamoud, Y.A., Li, Y., & Shaghaleh, H. (2022). Subsurface drip irrigation with emitters placed at suitable depth can mitigate N2O emissions and enhance Chinese cabbage yield under greenhouse cultivation. *Agronomy*, *12* (3), 745. https://doi.org/10.3390/agronomy12030745

Hara, T., & Sonoda, Y. (1982). Cabbage-head development as affected by nitrogen and temperature. *Soil Science and Plant Nutrition*, *28* (1), 109-117. https://doi.org/10.1080/00380768.1982.10432376

Hou, X.Y., Wang, F.X., Han, J.J., Kang, S.Z., & Feng, S.Y. (2010). Duration of plastic mulch for potato growth under drip irrigation in an arid region of Northwest China. *Agricultural and Forest Meteorology*, *150* (1), 115-121.

Ilin, Ž., Adamović, B., Ilin, S., & Žnidarčič, D. (2017). Early potato. In: Baudoin, W., Nersisyan, A., Shamilov, A., Hodder, A., Gutierrez, D., Pascale, S.D.E., & Tanny, J. (Eds.). *Good Agricultural Practices for greenhouse vegetable production in the South East European countries-Principles for sustainable intensification of smallholder farms*, (pp. 389-401). FAO, Rome.

Ilić, Z., & Milenković, L. (2022). Kako ublažiti negativni uticaj klimatskih promena na proizvodnju povrća? *Zbornik radova: Nacionalni naučno-stručni skup sa međunarodnim učešćem Biotehnologija i savremeni pristup u gajenju i oplemenjivanju bilja,* (pp. 15-49). Smederevska Palanka.

Imtiyaz, M., Mgadla, N.P., Chepete, B., & Manase, S.K. (2000). Response of six vegetable crops to irrigation schedules. *Agricultural water management*, *45* (3), 331-342.

Kalloo, G., & Bergh, B.O. (1993). *Genetic Improvement of Vegetable Crops*. Elsevier Science.

Karagić, Đ. (1998). Evapotranspiracija, prinos i kvalitet kupusa u zavisnosti od predzalivne vlažnosti zemljišta i roka sadnje. Univerzitet u Novom Sadu, Poljoprivredni fakultet.

Karagić, Đ., Dragović, S., & Maksimović, L. (2001). Prinos i evapotranspiracija kupusa u zavisnosti od roka sadnje. Zbornik radova 1 Međunarodnog simpozijuma Hrana u 21. veku (1), (pp. 125-131). Subotica.

Khramov, R., Kosobryukhov, A., Kreslavski, V., Balakirev, D., Khudyakova, A., Svidchenko, E., & Luponosov, Y. (2022). Luminescence of agrotextiles based on red-light-emitting organic luminophore and polypropylene spunbond enhances the growth and photosynthesis of vegetable plants. *Frontiers in Plant Science*, *13*, 827679. https://doi.org/10.3389/fpls.2022.827679

Kim, H.K., Lee, S.Y., Kwon, J.K., & Kim, Y.H. (2022). Evaluating the effect of cover materials on greenhouse microclimates and thermal performance. *Agronomy*, *12* (1), 143. https://doi.org/10.3390/agronomy12010143

Kołota, E., & Chohura, P. (2015). Control of head size and nutritional value of cabbage by plant population and nitrogen fertilization. *Acta Scientiarum Polonorum Hortorum Cultus*, *14* (2), 75-85.

Lešić, R., Borošić, J., Buturac, I., Ćustić-Herak, M., Poljak, M., Romić, D. (2016). *Povrćarstvo.* III dopunjeno izdanje. Zrinski d.d., Čakovec.

Lüling, N., Reiser, D., Straub, J., Stana, A., & Griepentrog, H.W. (2022). Fruit volume and leaf-area determination of cabbage by a neural-network-based instance segmentation for different growth stages. *Sensors*, *23* (1), 129.

Malhotra, S.K., & Srivastva, A.K. (2014). Climate smart horticulture for addressing food, nutritional security and climate challenges. In Srivastava A.K. (Ed.), *Shodh Chintan: Scientific Articles*. (pp. 83–97). New Delhi, India: ASM Foundation. doi: 10.56093/ijas.v87i1.67138

Malhotra, S.K., & Srivastava, A.K. (2015). Fertilizer requirement of Indian horticulture–An analysis. *Indian Journal of Fertilizer*, *11* (7), 16-25.

Maršić, N.K., Šturm, M., Zupanc, V., Lojen, S., & Pintar, M. (2012). Quality of white cabbage yield and potential risk of ground water nitrogen pollution, as affected by nitrogen fertilisation and irrigation practices. *Journal of the Science of Food and Agriculture*, *92* (1), 92-98.

Momirović, N. (2004). About contemporary technology of brassica vegetable growing. *Povrtarski glasnik* (Serbia and Montenegro), *2* (3), 5-10.

Osher, Y., Chalupowicz, D., Maurer, D., Ovadia-Sadeh, A., Lurie, S., Fallik, E., & Kenigsbuch, D. (2018). Summer storage of cabbage. *Postharvest Biology and Technology*, *145*, 144-150. https://doi.org/10.1016/j.postharvbio.2018.07.006

Ponjičan, O., Kiss, F., Ilin, Ž., Adamović, B., Sabadoš, V., Sedlar, A., & Višacki, V. (2021). Influence of plastic mulch and fertilization on the environmental impact of spring cabbage production. *European Journal of Agronomy*, *122*, 126170. https://doi.org/10.1016/j.eja.2020.126170

Radovich, T.J., Kleinhenz, M.D., Delwiche, J.F., & Liggett, R.E. (2004). Triangle tests indicate that irrigation timing affects fresh cabbage sensory quality. *Food quality and preference*, *15* (5), 471-476.

Radovich, T.J., Kleinhenz, M.D., & Streeter, J.G. (2005). Irrigation timing relative to head development influences yield components, sugar levels, and glucosinolate concentrations in cabbage. *Journal of the American Society for Horticultural Science*, *130* (6), 943-949.

Seidel, S.J., Werisch, S., Schütze, N., & Laber, H. (2017). Impact of irrigation on plant growth and development of white cabbage. *Agricultural water management*, *187*, 99-111.

Shock, C.C., & Wang, F.X. (2011). Soil water tension, a powerful measurement for productivity and stewardship. *HortScience*, *46* (2), 178-185.

Stanciu, I. (2023). Research on the Culture of Cabbage and the Possibilities of Increasing the Early Production. In El-Esawi M (Ed.), *Recent Trends in Plant Breeding and Genetic Improvement*. IntechOpen; 2024. Available from: http://dx.doi.org/10.5772/intechopen.1001930

Suh, J., Son, B., Kang, J., Choi, Y., Lee, Y., & Park, Y. (2012). The Effect of High Temperatures on the Growth of Oriental Cabbages. Poster Board. ASHS Annual Conference, Miami, Florida, USA.

Žnidarčič, D., Kacjan-Maršić, N., Osvald, J., Požrl, T., & Trdan, S. (2007). Yield and quality of early cabbage (*Brassica oleracea* var. *capitata* L.) in response to within-row plant spacing, *Acta agriculturae Slovenica*, *89* (1), 15-23. https://doi.org/10.2478/v10014-007-0002-1

Vlajić, S., Maširević, S., Barać, R., Iličić, R., Gvozdanović – Varga, J., & Božić, V. (2017). Bolesti kupusa tokom 2016. godine. *Zbornik radova* 1 *XXII Savetovanje o Biotehnologiji sa međunarodnim učešćem* (pp. 309-313). Čačak.

Xianbing, W., Meijian, B., Yinong, L., Taisheng, D., Shaohui, Z., Yuan, S. & Yanan, L. (2020). The effect of fertigation on cabbage (*Brassica oleracea* L. var. *capitata*) grown in a greenhouse. *Water*, 12, 1076, 2-19. https://doi.org/10.3390/ w12041076

Yamamoto, T., Matsuo, K., & Yamasaki, A. (2015). Effect of seedling transplant depth on the yield, lodging, and root distribution of cabbages grown for processing under an integrated mechanical cultivation system. *Root Res*, *24*, 3-10.

Yue, L., Li, G., Dai, Y., Sun, X., Li, F., Zhang, S., & Zhang, S. (2021). Gene co-expression network analysis of the heat-responsive core transcriptome identifies hub genes in Brassica rapa. *Planta*, *253* (5), 111. https://doi.org/10.1007/s00425-021-03630-3

https://www.hidmet.gov.rs

https://www.stat.gov.rs

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UTICAJ KLIMATSKIH PROMENA NA PROIZVODNJU KUPUSA

Janko F. Červenski[1*], Vlajić A. Slobodan[1], Boris D. Adamović[2], Đorđe S. Vojnović[2] i Srđan D. Zec[1]

[1]Institut za ratarstvo i povrtarstvo,
Institut od nacionalnog značaja za Republiku Srbiju,
Maksima Gorkog 30, 21000 Novi Sad, Srbija
[2]Univerzitet u Novom Sadu, Poljoprivredni fakultet,
Trg Dositeja Obradovića 8, 21000 Novi Sad, Srbija

R e z i m e

Za rast i razvoj kupusa, optimalne temperature su od 15 do 18ºC. Međutim, veći deo vegetacionog perioda kupusa je izložen temperaturama preko 20 ºC. Iz razloga dobijanja što veće cene na zelenoj pijaci, proizvođači kupusa kreću sa što ranijim rokovima sadnje kupusa (ranog ili kasnog jesenjeg). Na sam kupus se „vrši pritisak” kroz obilnije navodnjavanje, gušći sklop, prihranu i zaštitu da bi u što kraćem roku formirao tržišno zbijenu glavicu (tehnološki zrelu), koja bi ostvarila što bolju dobit na tržištu. U cilju poboljšanja efikasnosti korišćenja vode i prilagođavanja kupusa toplijim i suvljim uslovima, za preporuku je korišćenje modifikovanih proizvodnih sistema. Akcenat možemo staviti na pomeranje datuma setve ili sadnje u cilju borbe protiv sve prisutnijeg povećanja temperature i perioda nedostatka vode tokom sezone uzgoja kupusa. Cilj ovog rada je ukazati na uticaj temperaturnog i vodenog stresa, te dati određena rešenja koja se mogu praktično primeniti radi ublažavanja negativnog uticaja pomenutih stresova na proizvodnju kupusa. Prednost bi trebalo dati razvoju proizvodnih sistema za poboljšanje efikasnosti korišćenja vode prilagođenih uslovima toplog i suvog vremena. Navodnjavanje kupusa bi trebalo organizovati sistemom kap po kap. Ovim sistemom navodnjavanja racionalnije trošimo vodu, uz mogućnost uporednog prihranjivanja i zaštite.

Ključne reči: temperaturni stres, vodni stres, kupus, navodnjavanje, malčiranje.

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*Autor za kontakt: e-mail: janko.cervenski@ifvcns.ns.ac.rs