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THE MOST SUITABLE IRRIGATION METHODS IN CABBAGE CROPS (*BRASSICA OLERACEA* L. VAR. *CAPITATA*): A REVIEW

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Abstract

To achieve high horticultural productivity, it is known that an optimal supply of irrigation water is required. Cabbage (Brassica oleracea var. capitata) has been classified as an intermediate sensitive to water stress. Also, the development of plants under drought stress can have effects on quality and productivity, so it is necessary to use water efficiently when it comes to cabbage crops. Also, many studies show that the early effects of stress against plants can be compensated by an optimal supply of water in the growth stages. This review paper collected the latest information from the literature on cabbage water requirements, listing the most effective irrigation methods that lead to water efficiency in crops and irrigation programming to have the best cabbage production in the field.

Key words*: irrigation, cabbage, water efficiency, production.*

INTRODUCTION

Water is the dominant factor for crop diversification and production. More than 80% of water assets have been used for agricultural irrigation (Sitta., 2011). To handle the water-shortage, it is fundamental to adopt water saving agriculture counter measures as adequate use of irrigation water is becoming increasingly crucial.

Irrigated crop production is important for global food security for the reason that it contributes around 40% to the total food supply for the entire world (Garces-Restrepo et al., 2007). Irrigated agriculture covers only 20% of total arable land, however, it consumes more than two-thirds of the total available freshwater (Chai et al., 2016). The world population is growing at an alarming rate, and the demand for good quality, non-saline water is rising considerable (Evans and Sadler., 2008).

Cabbage is one of the most important brassica vegetable cultivated in Romania and is known for its diversity and culinary properties, and for its adaptability to divers environmental conditions (Voican et al., 2002). According to Romanian Ministry of Agriculture and Rural Development the total production of cabbage in 2018 was 1065.5 thousand tons harvested from an area of 17.9 thousand ha.

Irrigation is one of the major uses of water throughout the world. Is very important for every vegetable crop and depending on planting and growing season, cultivated variety and should not exceed the optimal limits because excess of moisture leads to cracking of the heads, disease of the plants and suffocation of the roots (Munteanu et al., 2001).

Cabbage yield is mostly affected by different factors like as irrigation and soil fertility. This vegetable requires high amounts of N, K, S and also needs an optimum soil moisture of 75-80% and even 90% during the growth and maturation of the heads and a relative air humidity of 85-90% (Abdrabbo et al., 2015; Voican et al., 2002).

Increasing the volume of water administrated, head size and weight, leaf weight and, yield can be improved. Cabbage watering methods are numerous, sprinkler irrigation is mostly used and is followed by furrow, border, basin and trickle irrigation methods (Bilal Acar et al., 2006).

Sprinkle irrigation is similar to rainfall, water is distributed through a system of pipes usually by pumping and then sprayed into the air and irrigated entire soil surface through spray heads so that it breaks up into small water drops which fall to the ground (Christiansen., 1942).

Furrow irrigation is one of the most common method of surface irrigation and is mostly associated with low application efficiency and high labour requirements for land levelling.

(Sayari et al., 2019). Moreover, this system greatly reduces the amount of surface wetted, leading to less evapotranspiration (Jemal Nurr, 2018) and even if it has some advantages, it does not ensure a high humidification of the air (Munteanu et al., 2001).

Trickle irrigation consists in a slow process of delivering water to the soil surface through a plastic pipe that is provided with several emitters. (Bucks et al., 1974). A lot of proponents sustain that the most important advantage of trickle irrigation refers to its ability to apply small quantities of water at frequent intervals and leads to improvement of quality and quantity of production, reduce labour cost and increase fertilizer efficiency. (Goldberg et al., 1970)

The purpose of this review investigation was to identify and combine different information on the most suitable irrigation methods in cabbage crops and to evaluate the cabbage water requirements (quantity and frequency of water application) to achieve an increase of production by triangulating different literatures on the topic.

MATERIALS AND METHODS

Cabbage (*Brassica oleracea* L. var. *capitata*) is one of the most widely grown, traded, and consumed horticultural crops worldwide and according to FAOSTAT in 2019 the area harvested of cabbage and other brassicas at monial level was 2 446 294 ha and the production was 70 150 406 tons. In the same year, in Europe the production of cabbage and other brassicas was 9 719 903 tons compare to an area of 325 804 ha. In Romania the total area harvested of cabbage and other brassicas, in 2019, was 28 790 ha and yield were 214 286 kg ha^{-1}. This vegetable is known and preferred by consumers due to its high nutritional value beneficial to human health which is rich in vitamins, fibres, polyphenols and flavonoids (Nawaz et al., 2018).

Tiwari et al. and Stan et al. claim that the nutritional value of 100 g of edible portion of cabbage contains 1.8 g protein, 0.1 g fat, 4.6 g carbohydrate, 0.6 g mineral, 29 mg Ca, 0.8 mg Fe, 14.1 mg Na, and in addition contains the vitamins C in proportion of 50 mg 100 $g^{-1}$and B in proportion of 1.1-1.2 mg 100 g^{-1} and vitamin A. *Brassica oleracea* var. *capitata* is a rich mine of bioactive phytochemicals. The main compounds that can be found in cabbages are carotenoids, alkaloids and phenolic compounds (Ramirez et al., 2020).

Phenolic compounds are considered to grant to the health benefits associated with dietary consumption of *Brassicaceae* species such as anticarcinogenic power, antioxidant capacity, anti-aggregation activity and activation of detoxification enzymes, along others. The main phenolic compounds that can be found in cabbages are kaempferol glucosides and epicatechins (Li et al., 2018; Fusari et al., 2019).

Carotenoids are highly pigmented phytochemicals, some of them as β-carotene and α-carotene and β-cryptoxanthin have provitamin A activity since they act as precursors of vitamin A and, therefore, acquires an important function as a human health promoter. The main carotenoids that can be found in cabbages are luteolin, followed by β-carotene, zeaxanthin, and α-carotene (Kaulmann et al., 2016).

Alkaloids are secondary metabolites of plants synthesized from amino acids. These compounds have also been reported in cabbage cultivars and also in cabbage seeds (Guriya et al., 2015; Khalid et al., 2014).

Cabbage is consumed throughout the year and is a species that easily fits into vegetable crops and, in the same time, can be grown in different systems and types of crops. During transport, temporary storage and recovery, the harvest is less perishable and the expenses per unit area are reduced due to the complete technology of the works (Stan et al., 2001).

Among various factors affecting crop growth, water and fertilizer are the leading components that can be adjusted and controlled. In certain agricultural production, to obtain greater yields, redundant water use has become standard practices, and these habits not only leach nutrients from surface soil to deep soil, reducing water and nutrient use capability (Quiñones et al., 2007; Li et al., 2017), but may also cause soil environmental degradation (Zhang et al., 2011; Kuscu et al., 2014).

RESULTS AND DISCUSSIONS

CABBAGE WATER REQUIREMENTS

Cabbage has been classified as intermediately vulnerable to water stress, with the head formation cycle being more sensitive than the cycle before (Adeniran et al., 2010). The trials of these authors were in line with (Thomas et al., 1970) which reported that the most demanding irrigation period for cabbage appeared during the last 3 to 4 weeks before harvest.

Cabbages need frequently irrigation to ensure hasty growth and evenness of maturity. They can be irrigated by moveable spray lines, travelling irrigators or solid set, or, if the soil is suitable and water available, flood irrigation might be more productive. Likewise, cabbages grown in beds will require more irrigation than those grown on the flat. On the other hand, soil type and weather will also influence the frequency of irrigation. Hence, the use of tensiometers or other measuring equipment will improve yields and reduce water costs (Murison., 2006).

Doorenbos and Pruitt (1977) define the crop water requirements as "the depth of water needed to meet the water loss through evapotranspiration (ET crop) of a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment". Crops are categorized according to their yield response to water namely: crops sensitive to water stress and those tolerant to drought. Cabbage has been classified as an intermediate sensitive to water stress, and the highest requirements for water are manifested in the formation phase of the head, but also during the planting and formation of leaf rosette even if the quantitative requirements are lower (Stan et al., 2001).

Cabbage should be irrigated to maintain available soil water above 50% because an insufficient amount of water leads to a decrease in quantitative and qualitative production. (Vittum et al., 1967). The critical period for irrigation in humid and semi humid regions is usually during the last 3 to 4 weeks of head formation and development. Irrigation not only increases the acre yield of marketable cabbage but also increases the average weight per head (Nettles et al., 1952; Vittum and Peck, 1956).

Cabbage has been made known as intermediately susceptible to water stress, with the most critical irrigation period occurred during the last 3 to 4 weeks before harvest (Smittle et al., 1994). Efficient water management is a prerequisite to successive cabbage production. Water requirements vary from 380 to 500 mm depending on climate and length of growing season after (FAO water development and management unit, 2012).

Cabbage does not tolerate drought and prefers cultivation on a modeled field so that it can be irrigated on furrows. Usually, early cabbage is less irrigated due to the water reserve in the soil in winter-spring and the short vegetation period, the rest of the cabbage species are irrigated abundantly during the vegetation period depending on the climatic conditions of that year. Muddling should be avoided because it promotes the appearance of diseases, especially cabbage hernia (*Plasmodiophora brassicae*) (Stoian., 2006).

In a research of Smittle et al. (1994) was studied the yield and water-use responses of cabbage to three irrigation regimes. Water was applied with a hand-held sprinkler nozzle and irrigation was scheduled by measured soil water deficits. Total production of cabbage and marketable cabbage yield were highest with irrigation application when the soil water tension at 10 cm was less than 25 kPa.

According to Mihalache et al. (1985), at a precipitation amount of 400-500 mm, the irrigation regime and scheme for early cabbage, summer cabbage and autumn cabbage is presented in Table 1.

Irrigation depending on climate crop development, and soil type and the frequency of irrigation varies between 3-12 days. If available water supply is limited, early irrigation should not be practiced unless these can be continued until the end of the crop growing period. Water saving could be made in the beginning of the crop growing period (Maynard and Hochmuth, 2007).

Table 1. Irrigation regime and watering scheme o cabbage

Crop	The amount of precipitation: 400-500 mm			
	Watering norm m^3 h^{-1}			Watering scheme
	Irrigation	Watering	No. of watering	
Early cabbage	2400-2600	400-500	5-6	I-II: after 10-12 days: 300-350 m^3 ha^{-1}; III-IV: after 8-10 days: 400 m^3 ha^{-1}; V – 400-500 m^3 ha^{-1};
Summer cabbage	3000-3500	400-600	4-5	I-II: after 10 -12 days 400-450 m^3 ha^{-1}; III-V: 400-500 m^3 ha^{-1};
Autumn cabbage	4000-4500	500-600	7-8	I-IV: frequently, after 6-7 days: 400-450 m^3 ha^{-1}; V-VII: after 8-10 days: 500-600 m^3 ha^{-1};

IRRIGATION METHODS

To ensure the optimal use of water resources and the distribution uniformity of water is at an acceptable level, the condition of sprinkler packages, the pressure variation within the system, the strength and direction of wind, needs to be correctly manage. (Ascough., 2002).

Sprinkler irrigation have some benefits like as: produces a favourable effect on the microclimate, eliminates the division of the land through a dense network of canals, allows watering of crops located on lands with high permeability and allows accurate dosing of irrigation water (Stan., 2010).

Sanchez et al. (1994) found a significant yield increase when a sprinkler irrigation is applied and sprinkler-applied N fertilizer on a coarse-textured soil. In the same study it is also argued that the deficit and excess irrigation reduce cabbage production.

In a study carried out in Malawi on dry season of 2006-2007 it was evaluated yield response of cabbage to irrigation frequency. The cabbage was subjected to three irrigation frequencies: F1 – irrigated twice a week, F2 – irrigated once a week and F3 – irrigated once a fortnight. The irrigation system used in this experiment was furrow irrigation and the water was applied through PCV pipes with a diameter of 10 cm, in furrows 5 m long. F1 resulted in highest yield and WUE (water-use efficiency) while F3 yielded lowest. Comparing all the irrigation frequencies, F3 turns out to be the most effective water saving irrigation frequency (Kadyampakeni., 2013).

On the other hand, Singh and Alderfer have demonstrated that when applying an irrigation at 100 kPa soil water tension during growth and 1000 kPa before head formation and 100 kPa after head formation, marketable yields of cabbage are similar (Singh et al., 1966). In Texas, when cabbage was produced during the winter and was applied an irrigation at 360 kPa soil water tension, the yield was reduced (Thomas et al., 1970).

In a study release in 2016 in Romania about water use efficacy on cabbage and cauliflower treated with a new biostimulator composition, total irrigation for cabbage vegetation period was 334 mm and 250mm for 100% and 75%, respectively and was demonstrated that a percent of 75% ETc (evapotranspiration crop) deficit irrigation significantly reduce total and marketable yield.

Optimum yield of cabbage the soil water deficiency in most climates should not exceed 35% to 40% of the total available soil water. Due to this light irrigation administration are recommended. Therefore, studies show the effects of varying water supply on the water regime and productivity of head cabbage. Field trials with mid-early and mid-late cabbage cultivars using sprinkler irrigation to maintain field water capacity at 80 per cent resulted in highest yield (Gancharyk and Paulenka., 1975).

For the cabbage crops it is necessary to know the quantity of water and when it should be applied for enhancing its productivity. Drip irrigation is one of the irrigation methods that will help to apply water evenly to the field in the area of the roots and at the same time at the desired intervals. In a field experiment conducted in India indicate that a water use efficiency was registered in treatment with drip irrigation at 60% ET (evapotranspiration) scheduling at once in two days in the first year. For higher productivity of cabbage head and higher water use efficiency, drip irrigation is very effective at 80% ET compared to irrigation at 100% ET scheduling at once in two days (Harris et al., 2014).

Xianbing et al. performed a study in 2020 on fertigation on cabbages grown in a greenhouse

and as result, they recommend that when cabbage is planted in greenhouses, the irrigation application of drip irrigation under mulch should be approximately 114.7-125.0 mm and the N fertilization should be 200 kg ha^{-1}.

In a study conducted by Fasika Terefa in 2017 the results obtained from the experimentation showed that sprinkle irrigation scheduling at six days and nitrogen fertilizer at an amount of 92 kg ha^{-1} were optimum for cabbage growth. This optimum treatment combination resulted in higher nitrogen content (3.35%), higher nitrogen recovery (89.9%) and higher water use efficiency (152.47 kg ha^{-1} mm^{-1}) for cabbage crop. Comparing of farmer practice with 6 days irrigation scheduling and 92 kg of nitrogen fertilizer and with 3 days and 9 days irrigation scheduling by 92 kg ha^{-1} nitrogen fertilizer all the above variables were greater in this optimum treatment combination than in farmers usual management.

It is essential to develop irrigation scheduling strategies under local climatic conditions to utilize limited water resources efficiently and effectively.

CONCLUSIONS

Water requirement of cabbage varies with climate, crop variety, soil type, and agricultural practices. On sandy soil frequent cultivation of cabbage is highly productive in comparison to clay soil. This is because of down word and lateral movement of soil water is prevailed in sandy and clay soil respectively. As follows, yield and water use efficiency of irrigated cabbage generally increased with increasing levels of management options. As a result, crop water requirement is comprehensive to crop modelling strategies which are dedicated to sustainable agriculture particularly in the view of climate change. Thus, crop production should be supported by prediction data.

In summary, the optimum yield was achieved by providing an amount of irrigation water of not less than 400m^3 ha^{-1} sprinkle and furrow irrigation. On the other hand, organic acid content was higher in cabbage grown under low soil water content. Likewise, the amount of water used for drip irrigation should be approximately 125-150 m^3 ha^{-1} without exceeding six days between irrigation moments for any type of irrigation method.

Also, it is important to keep into account the amount of precipitations throughout the vegetation period and the climate of the area where the crop is being established. It is critical to not skip the most precarious moments of watering, and these stages are when the seedling has 6-7 leaves and at the beginning of the head formation.

These results can be considered as a strategy for water management in white cabbage (*Brassica oleracea* L. cv. *capitata*).

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