Productivity of leafy green vegetable Kale in soilless cultivation conditions

Accepted 12th May, 2019

ABSTRACT

Valuable leafy green vegetable kale \(\text{Brassica oleracea}\) var. Sabellica L., also known as a curly cabbage, firstly was introduced in Armenia, and its high productivity and prospectivity were studied and established in water stream hydroponics experimental modules (gully, cylindrical and continuous), classical hydroponics, as well as in soil culture. In kale, received from different hydroponic systems, the raw material and the output of pharmaceutical indices (vitamin C, extractive substances, flavonoids and tannins) are higher with 1.5-1.8 and 1.2-2.3 times, respectively as compared with soil culture. Water stream hydroponics is safer radio-ecological, biotechnological method for the production of raw material than classical hydroponics and soil culture.

Key words: Water stream hydroponics, kale, \(^{90}\text{Sr},^{137}\text{Cs}\), bio-pharmacochemical analyses.

INTRODUCTION

Vegetables take big place in human's food being inseperable part of meals. They play important role in regulating human's nervous system, digestive and other organs activity, and also increase organism’s resistance. Especially, such said salad vegetables that are used in raw condition without cooking have great value. In recent years, non-traditional cultivated plants that already have large demand in consumer market have conquered their specific place in the range of vegetable cultivated plants. The range of such cultivated plants includes the Brussels sprout, pak choi, broccoli and etc. from the cabbage family, which are considered as delicacy cultivated plants, differing from the other kinds of cabbage with their nutritional properties.

Taking into account the above mentioned, valuable prospective leafy green vegetable kale was firstly introduced into Armenia by the authors of the present study and it was purposed to study the growing possibility and productivity of this cultivated plant under soilless culture conditions (hydroponics), as well as to detect optimal conditions to receive quality, ecologically more safe plant raw material in the Institute of Hydroponics Problems (IHP).

In this study, experiments were done in experimental modules of water stream hydroponics of IHP\(^1\), as well as in conditions of classical hydroponics (CH) and soil culture.

MATERIALS AND METHODS

Kale is a biennial vegetable that belongs to the Brassicaceae family. It has green or violet curly leaves that do not form cabbage head. Kale is nearer to the wild cabbage based on its properties and chemical content. In food, its leaves are mainly used. The plant blooms and gives seed in the next year (http://academics.hamilton.edu/foodforthought/our_research_files/cabbage_cauliflower_kale.pdf, http://aggie-horticulture.tamu.edu/archives/parsons/publications/vegetabletravelers/kale.html).

---

\(^1\) In the IHP NAS RA it was developed and licensed new, modern system «water stream hydroponics» for the soilless production of different plant species using polymeric film that joins the rank of already existed in the world known hydroponic systems with its low cost, more automated system and beforehand instructed program [11].
Kale contains huge amount of proteins equal to meet products (4.3%), all 9 essential amino acids (Val, His, Leu, Lys, Trp and etc.) and 11 non-essential amino acids. In fresh kale leaves, the glutamic acid, proline and aspartic acid are dominant in total amino acid content (12, 12 and 10%, respectively). The amount of Leu, Lys, Val, Arg and Ala ranges from 6-8% of total amino acid content and the amount of Tyr, Phe, Thr, His, Ser and Gly ranges from 3-5%.

The sulphur containing amino acids cystine (1.6%) and Met (2%) have the lowest proportion (Lisiewska et al., 2008). It is rich also with fatty acid omega 3 (Abbery et al., 2018), vitamins (A, C, K, PP, B and etc.), easily digestible Ca (120-150 mg), Mg (34-47 mg) and other mineral substances (K, P, Na, Fe, Zn, Se, Mn, Cu and etc.). The content of lutein that exists in plant protects human eye from sun's ultraviolet rays. Frequent use of this plant in diet protects human organism from a number of diseases, particularly from cardiovascular, gastrointestinal, eye (glaucoma) diseases, diabetes, malignant tumors and etc. (Giacoppo et al., 2013). Kale contains 45 different kinds of flavonoids (sulphoraphane, indole-3-carbinol and etc.) that provide the antioxidant and antiinflammatory properties of this plant, too (Kuntz and Kunz, 2014; Olsen et al., 2009; Sikora and Bodziarczyk, 2012). They increase organism's immunity and decrease the cholesterol level in blood. By regulating glucose level, it promotes the decrease of weight. High amount of calcium, contained in the plant (2 times more than in milk) have influence on the bone cells generation and regeneration, by that preventing rickets, osteoporosis and teeth fragility. At present, kale is widely spread in USA, Western Europe, Japan and in several other countries (Soo et al., 2008).

The experiments were done in conditions of water stream (cylindrical, gully, continuous), classical hydroponics on the volcanic red slag substrate with the 3-15 mm diameter and in conditions of soil culture with 8 plant/m² density. Plants’ nutrition was done with Davtyan 0.75N nutrition solution (Davtyan, 1969). In water stream hydroponics, the nutrition solution was pumped periodically, irreversibly like a jet during a day about 6-20 times (dependent on climate conditions) with a 10-15 s duration to the root-bearing stratum of each plant. The amount of one-time giving solution was 20-50 ml. Plants were nourished 1-3 times during a day in CH and once during 3-4 days in soil culture, maintaining all adopted agrotechnical rules (soil aeration, weeds removal, periodic watering, fertilization and etc.) (Mairapetyan, 1989). Leaves harvest was done during July - October.

During vegetation biometric measurements, also bio-pharmaceutical analyses were done. In plant raw material, the content of extractive substances, tannins and humidity was determined according to Sph XI (1990), flavonoids were identified according to Borisov et al. (1975), vitamin C was estimated according to Yermakov et al. (1952). Technogenic RN (radionuclides) in samples was determined using radiochemical methods with small UMF-1500 background radiometer (Pavlotskaya, 1966). The concentration limit values (ACL) have been given according state standards of Russian Federation (Ministry of Health of RF, 2002; Supplement of technical regulations of fresh fruit vegetable, 2006) that have been officially accepted also in Republic of Armenia. Received results were statistically analyzed according to Dospekhov (1985).

RESULTS AND DISCUSSION

From the analysis of the data presented in Table 1, it can be seen that during vegetation in all variants, except continuous hydroponics, maximal output of fresh plant raw material was ensured in July during first harvest. Besides, kale raw material received using different hydroponic systems 1.5-1.8 times exceeded soil culture, at the same time gully and classical hydroponic systems 1.1-1.3 times surpassed the experimented with other hydroponic variants with the yield, plant height and stem thickness (Figure 1).

In all hydroponic variants, except continuous hydroponics, the maximal accumulation of fresh plant raw material (1.6-2.9 times) was observed in July. It is important to mention that it was noticeably high (2.8-7.0 times) in soil control during the first month.

It is necessary to emphasize that growth conditions have significant influence on the pharmacological indices of plant raw material (Table 2). The increase of extractive substances content (1.2-1.5 times) was stated in all water stream hydroponic modules and relatively high content of flavonoids was established in gully system (by 10-35%). In hydroponics, the content of tannins was fluctuated between 2.0-2.2% that conceded insignificantly in the same index of soil (2.4%). It was revealed also the influence of cultivation conditions on the biosynthesis of vitamin C. cylindrical and continuous hydroponic systems exceeded 1.3-1.5 times the conditions of gully, classical hydroponics and soil by the content of vitamin C (Table 2). Due to high crop capacity of hydroponic plants, the difference between plants of hydroponic systems and soil is significant from the point of mentioned indices: in the case of extractive substances, the difference is 1.7-2.3 times, for flavonoids it is 1.2-2.0 times, in the case of tannins it is 1.2-1.6 times and for vitamin C it is 1.8-2.2 times.

Plant cultivation conditions influenced specifically the RN accumulation in plant raw material (Table 3). Thus, plants in water stream hydroponics are concede by the content of ⁹⁰Sr and ¹³⁷Cs plants grown as in classical hydroponics (1.2-1.3 and 1.1-1.2 times), as in soil (1.8-2.0 and 1.4-1.5 times) conditions.

In different hydroponic systems, the content of ⁹⁰Sr in kale's plant raw material exceeded the content of ¹³⁷Cs in all 1.1-1.2 times and in soil culture, it exceeded 1.5 times.

Probably, RN entered into kale through the roots from the nutrient solution or irrigation water and soil through
Table 1: Fresh mass of kale during vegetation in hydroponics and soil, g/plant.

| Variant    | July | August | September | October | ∑    |
|------------|------|--------|-----------|---------|------|
| Cylindric  | 263  | 132    | 95        | 100     | 590  |
| Gully      | 293  | 184    | 142       | 100     | 719  |
| Continuous | 108  | 198    | 161       | 114     | 581  |
| CH         | 289  | 141    | 133       | 143     | 706  |
| Soil (control) | 224 | 80     | 65        | 31      | 400  |
| LED₁ª²     | -    | -      | -         | -       | 28.7 |

LED₁ª² – the least essential difference.

![Biometric data of kale in hydroponics and in soil](image)

**Figure 1:** Biometric data of kale in hydroponics and in soil.

Table 2: The pharmacochemical indices of kale in hydroponics and in soil

| Variant     | Extractive substances | Total flavonoids, according luteolin | Tannins | Vitamin C | β-carotene |
|-------------|-----------------------|--------------------------------------|---------|-----------|------------|
|             | %                     | % output, g/plant                    | %       | output, g/plant | mg % | output, mg/plant | mg % | output, mg/plant |
| Cylindric   | 34.7±0.9              | 205                                  | 2.8±0.10| 16.5      | 2.0±0.10  | 11.8      | 1151            | 11.2±0.20  | 66.1    |
| Gully       | 36.2±0.9              | 260                                  | 3.8±0.15| 27.3      | 2.2±0.10  | 15.8      | 964             | 12.8±0.42  | 92.0    |
| Continuous  | 38.0±1.0              | 221                                  | 3.4±0.15| 19.8      | 2.2±0.12  | 12.8      | 1098            | 11.0±0.21  | 63.9    |
| CH          | 26.2±1.2              | 185                                  | 3.4±0.10| 24.0      | 2.2±0.11  | 15.5      | 1059            | 13.1±0.26  | 92.5    |
| Soil (control) | 28.1±1.4             | 112                                  | 3.4±0.11| 13.6      | 2.4±0.12  | 9.6       | 528             | 13.7±0.42  | 54.8    |

overground organs by the out of root way from the air basin (atmospheric precipitations, hydro and aerosols, dust).

Calculation showed that the values of observed ratios (OR) of $^{90}$Sr-$^{137}$Cs pair for kale ($^{90}$Sr/$^{137}$Cs in nutrient solution or in soil) in systems of nutrient solution – plant and soil – plant were 0.07-0.08 in hydroponics and 2.1 in soil. That is OR<1, which means that from the nutrient solution, the cultivated plants absorbed more intensively $^{137}$Cs in hydroponics and $^{90}$Sr in soil (Table 3). This was confirmed through the values of RN accumulation coefficients (OC) of cultivated plants ($\frac{\text{RN amount in plant, Bq/kg}}{\text{RN amount in nutrient solution, Bq/l or in soil, Bq/kg}}$). For the kale in hydroponics $^{137}$Cs AC > $^{90}$Sr AC 12.2-13.8 times, and in soil


Table 3: The content of $^{90}$Sr, $^{137}$Cs in kale’s plant raw material and RN relative indices in hydroponics and in soil.

| Variant     | $^{90}$Sr Bq/kg | $^{137}$Cs Bq/kg | OR, $^{90}$Sr/$^{137}$Cs | $^{90}$Sr AC Bq/kg | $^{137}$Cs AC Bq/kg |
|-------------|-----------------|------------------|--------------------------|-------------------|-------------------|
| Cylindric   | 9.9±0.32        | 8.7±0.25         | 0.08                     | 22.5              | 290               |
| Gully       | 8.8±0.20        | 8.3±0.20         | 0.07                     | 20.0              | 277               |
| Continuous  | 9.5±0.42        | 8.0±0.15         | 0.08                     | 21.6              | 267               |
| CH          | 11.8±0.20       | 9.8±0.26         | 0.08                     | 26.8              | 327               |
| Soil (control) | 17.6±0.20  | 11.9±0.21        | 2.1                      | 2.4               | 1.2               |
| ACL [1.4]   | 50              | 130              |                          |                    |                   |

$^{90}$Sr AC > $^{137}$Cs AC 2.0 times.

**Conclusion**

-Kale, cultivated in different hydroponic systems, exceeded with fresh plant raw material and with a number of biochemical indices (vitamin C, extractive substances, flavonoids and tannins) and conceded with radiochemical indicators to the same indicators of soil culture.

-Modern water stream hydroponic method is radioecologically more safe biotechnological method of production of plant raw material, than classical hydroponics and soil culture.

-Despite of the cultivation conditions, the content of controlled technogenic RN $^{90}$Sr, $^{137}$Cs in kale’s plant raw material did not exceed ACL.

-Kale production with modelling of the innovation technology of modern water stream hydroponics on hectares may satisfy the demand of our Republic.

**REFERENCES**

Abbe L, Pham TH, Anman N, Leke-Aladekoba A, Thomas RH (2018). Chemical composition of kale as influenced by dry vermicast, potassium humate and volcanic minerals. Food Res Int. 107:726-737.

Borisov MI, Belikov VV, Isakov TI (1975). Quantitative content of flavonoids in such plants as Asperula L. n Galium L. / Vegetative resources, 11(3): 351-358.

Cabbage 1 Scientific Classification and Etymology; Botanical Description. http://academics.hamilton.edu/foodforthought/our_research_files/cabbage_cauliflower_kale.pdf

Davyan GS (1969). Hydroponics as a industrial achievement of agrochemical science. XVII scientific reading dedicated to the memory of academician D.N. Pryanishnikov. Publishing house SA of Armenian SSR, 85 pp.

Dospechov BA (1985). Field experiment method, Moscow, Russia, (351pp.), pp. 223-228.

Giacoppo S, Galuppo M, Iori R, De Nicola GR, Cassata G, Bramanti P, Mazzen E (2013). Protective role of (RS)-glucoraphanin bioactivated with myrosinase in an experimental model of multiple sclerosis. CNS Neurosci Ther. 19(8):577-84.

Greeks and Romans Grew Kale and Collards. http://aggiehorticulture.tamu.edu/archives/parsons/publications/vegetabletravelsrs/kale.html

Hygienic requests to the safety and food value of food products. Sanitary-epidemiological rules and norms (2.3.2.1078-01). Moscow. Ministry of Health of RF, 164p., 2002. (in Russian)

Kuntz S, Kunz C (2014). Extracts from Brassica oleracea L. conv. acephala var. sabellica inhibit TNF-α stimulated neutrophil adhesion in vitro under flow conditions. Food Funct. 5(6):1082-1090.

Lisiewska Z, Knierik W, Koras A (2008). The amino acid composition of kale (Brassica oleracea L. var. acephala), fresh and after culinary and technological processing. Food Chem. 108(2): 642-648.

Mairapetyan SKh (1989). Culture of essential oil plants in open-air hydroponics. // Publishing house AS of Arm. SSR, Yerevan, 313 pp.

Mairapetyan SKh (2007). G.S. Davtian Institute of Hydroponics Problems of NAS RA in 60 years // Communications of IHP NAS RA, Yerevan, 31: 3-16.

Olsen H, Aaby K, Borge GI (2009). Characterization and quantification of flavonoids and hydroxycinnamic acids in curly kale (Brassica oleracea L Conv. acephala Var. sabellica) by HPLC-DADI-ESI-MSn. J Agric Food Chem. 57(7): 2816-2822.

Pavlotskaya F (1966). Methods of identification of Sr-90 and other long-lived isotopes in soil. In collection „Physical-chemical methods of soil study”, Moscow, p.12.

Silora E, Bodiarzych I (2012). Composition and antioxidant activity of kale (Brassica oleracea L. var. acephala) raw and cooked. Acta Sci Pol Technol Aliment. 11(3): 239-248.

Soo YK, Sun Y, Soo Mi K, Kye SP, Yang CL-K (2008). Kale Juice Improves Coronary Artery Disease Risk Factors in Hypercholesterolemic Men. Biomed. Environ. Sci. 21(2): 91-97.

State Pharmacopoea of USSR, XI volume, edition 2, Moscow: Medicine, 1990. (in Russian)

Supplement of technical regulations of fresh fruit vegetable – 1913-N decision on December 21 of RA government, 2006. (in Armenian)

Yermakov A, Arasimovich A, Smirnov-Ikonnikova M, Murri I (1952). Methods of plants biochemical study. Moscow, p. 89.

Cite this article as:

Daryadar M, Mairapetyan S, Tovmasyan AH, Aleksanyan JS, Tadevosyan AH, Kalachyan LM, Stepanyan BT, Gelstyan HM, Asatryan AZJ (2019). Productivity of leafy green vegetable Kale in soilless cultivation conditions. Acad. J. Environ. Sci. 7(5): 049-052.

Submit your manuscript at http://www.academiapublishing.org/journals/ajes