Comparative Study of Vegetative, Productive, and Qualitative Traits of Four Radish (Raphanus sativus L.) Cultivars.

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Abstract

A comparative study was conducted on four radish cultivars: black radish (R. sativus var niger), white radish (R. sativus var longipinnatus), watermelon radish (R. sativus var caudatus), which are of American origin and introduced to Iraq, and red radish (R. sativus var sativus), which is of local origin. The goal was to determine the best cultivar in terms of productivity and quality. A field experiment was carried out in a field located in the village of Imam Awn Bin Ali (AS), within the Al-Qasim district, south of Babil Governorate, Iraq, during the winter growing season from 23/2/2024 to 27/4/2024. The experiment was conducted using a Randomized Complete Block Design (R.C.B.D). Four varieties of radish were planted on plots, and each plot was repeated three times, making the total number of experimental units 12. The results showed that the black radish cultivar outperformed the others in all the studied vegetative traits, recording the highest averages for leaf number (12.666 leaves per plant), leaf area (5111.733 cm²), and dry weight of the vegetative mass (27.523 g). The black radish also recorded the highest averages for all the studied qualitative traits, with values of 57.800 Spad unit for chlorophyll index, 1.246% for protein content, and 4.360% for carbohydrate content. The vitamin content in black radish was also superior, with 0.226 µg of vitamin B1, 0.353 µg of vitamin B2, 4.590 µg of vitamin B3, 1.166 µg of vitamin B5, 1.133 µg of vitamin B6, 227.933 µg of vitamin C, 0.306 µg of vitamin E, and 0.490 µg of folic acid. Additionally, black radish outperformed the other cultivars in terms of nutrient content in the leaves, recording values of 0.199% nitrogen, 0.396% phosphorus, 2.946% potassium, 93.866 µg magnesium, 4.733 µg iron, and 9.366 µg zinc. On the other hand, the red radish cultivar showed the highest averages for productivity traits, including fruit diameter (24.066 cm) and dry weight of the fruit (11.100 g.(

Keywords: Raphanus sativus L.,Qualitative traits, Vegetative traits, Productive traits.

Introduction

Radish (Raphanus sativus L.) is a root plant from the Brassicaceae family and is considered an important global agricultural crop [25]. It is characterized by a variety of cultivars, colors, and shapes, such as red, white (Daikon), and black radish, making it a diverse and healthy food option suitable for different cultures and diets [31]. Its origin is believed to be China, from where it spread to other parts of the world. Radish is grown in China, Japan, and Korea, where Japan produces 3.7 million tons annually, while China cultivates it on an area of 1.2 million hectares, accounting for 6% of the total area planted with vegetables [29]. Radish grows

seasonally in temperate regions, especially in Asia and Europe, where its cultivars have diversified over time, starting with black radish, followed by white radish in the 16th century, and red radish in the 18th century [1]. In Iraq, radish is cultivated in the northern and southern plains, covering an area of 5098 dunams with a production of 15,492 tons in 2022, with the highest production found in the provinces of Dhi Qar, Najaf, and Nineweh [16.[

Radish is characterized by its diverse shapes (round, cylindrical, and tapered) and colors (red, white, pink, black). Its roots are edible and nutritionally valuable, as they can be consumed raw, cooked, or preserved. Radish contains minerals such as calcium, potassium, and iodine, in addition to active compounds like phenolics and alkaloids , which have medicinal effects, such as treating diabetes and cancer, due to compounds like sulforaphane and isothiocyanates. It also helps reduce body heat and moisturize the skin due to its water, vitamin C, and zinc content, making it a healthy, low-calorie option [16, 30, 19]. Every 100 grams of radish roots contains 94% water, 20 calories, 1 gram of protein, 4 grams of carbohydrates, 37 mg of calcium, and 31 mg of phosphorus, in addition to vitamins K, E, A, and the B-complex group .

Radish is grown in temperate climates and requires light, nutrient-rich soil. Black radish is distinguished by its large, round, black root and hot flesh. It contains 95% water, as well as potassium and phosphorus. Despite its limited spread in Arab countries, it is common in Europe and Asia, especially in Japan [11, 23], and has many health benefits, such as lowering cholesterol and improving liver functions, in addition to its antioxidant properties [26,15.[

White radish (Daikon) is a soft, white Japanese radish. It contains 18 calories per 100 grams and is a good source of vitamins C and A. It has a mild, sweet taste and is grown in the winter, but its maturation period is longer than that of red radish. It contains 4 grams of carbohydrates, 1 gram of protein, and 2 grams of fiber [27].Watermelon radish is a hybrid between red radish and Korean radish. It is distinguished by its white and green exterior and pink interior. It contains vitamins and flavonoids and has a sweet taste. It is grown in spring and autumn and prefers moist soil. Watermelon radish helps in the nutrition of pregnant women and improves skin elasticity, reducing wrinkles [17]. Red radish, one of the most famous varieties worldwide, originates from Japan and has a sweet and crunchy taste in its early stages. It contains compounds such as cyanidin and anthocyanin, which give it its red color [21], and has health benefits due to its vitamin and mineral content. It is used to treat kidney stones and liver diseases and contributes to improved digestion [4, 8.[

The importance of this research lies in:

-1 Selecting the cultivar most compatible with the environmental conditions in Iraq ensures optimal growth, adaptability, and agricultural productivity.

-2 Determining the cultivar with the highest nutritional content enhances the health benefits offered to consumers and adds value to the agricultural product.

Materials and Methods

Location of the Experiment :

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The experiment was conducted at the end of February, during the last phase of the winter season of 2024, in a field located in the village of Imam Awn Bin Ali (AS), within the Al-Qasim district, south of Babil Governorate, at a latitude of 32.5°N and longitude of 44.4°E. This area is situated 173 km south of Baghdad.

Seed Source :

The seeds of the four radish cultivars were obtained from the Office of Supplies for Ahl al-Bayt for Rare Seeds in Karbala Governorate. The cultivars were: black radish (R. sativus var niger), white radish (R. sativus var longipinnatus), watermelon radish (R. sativus var caudatus), which is of American origin introduced to Iraq, and red radish (R. sativus var sativus), of local origin.

Soil Preparation for Planting :

Soil preparation for planting was carried out through plowing, smoothing, and leveling using a manual plow. Ten soil samples were randomly taken from the experimental field before planting, from a depth of 0 to 30 cm. The samples were thoroughly mixed, and a composite sample was then collected for chemical and physical analysis, as shown in Table (1). Soil analysis was conducted in the Environmental and Pollution Laboratories in the Department of Life Sciences at the College of Science, University of Baghdad. The experimental field was divided into 12 plots, each with an area of 1.5 × 1 m².

Table 1. Chemical and Physical Analyses of the Field Soil

Trait	Value	Unit of Measurement
Available Phosphorus (P)	2.5	mg/kg
Available Potassium (K+)	66	mg/kg
Total Nitrogen (N)	86.17	mg/kg
Organic Matter	1.5	%
pH Level	7.1	—
Electrical Conductivity (1:1) (EC)	7	dS/m
Clay Content	79.6	%
Sand Content	12	%
Silt Content	8.4	%
Soil Texture	Clay	

ExperimentalDesign

A field experiment was conducted using a Randomized Complete Block Design (R.C.B.D). Each plot, with an area of 1.5 m², was divided into 3 rows with a 50 cm distance between rows. Each row contained 3 holes, with 9 holes in total per plot, and a 25 cm distance between each hole. A 25 cm distance separated the rows and the plot boundaries, and the space between plots was 50 cm. The plots were manually seeded with the four radish cultivars on 23/2/2024, with two seeds planted per hole. When the plants reached the 2-leaf stage, thinning was carried out to leave one plant per hole. Each plot was repeated 3 times, resulting in a total of 12 experimental units.

Agricultural Practices :

The soil was treated with the fungicide Hexaconazole before planting. The DAP

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fertilizer (Jordanian origin, containing 18% nitrogen and 46% phosphorus) was applied at a rate of 30 kg per don., in two doses. The first dose was applied during soil preparation, and the second was applied three weeks after the first dose, when the plants reached the 5-6 leaf stage. Additionally, urea fertilizer (46% nitrogen) was applied at a rate of 50 kg per don, spread on the soil surface according to the instructions of the Agricultural Guidance and Development Directorate of the Iraqi Ministry of Agriculture. Agricultural practices such as irrigation and weed removal were carried out as needed.

Studied Traits :

Three random plants were selected from each experimental unit for the study of the following traits:

Vegetative Traits:

.1 Number of leaves (leaves per plant,(

.2 Leaf area (cm^2), which was calculated using the cork-puncturing method based on the fresh weight of the leaves (cm^2) as described by [35.[

.3 Dry weight of the vegetative mass (g). The shoot was separated from the root, then the shoot was placed in pre-weighed perforated paper bags and left to air dry for a week, then the weight was measured using a sensitive electronic balance

Yield Traits:

.1 Root length (cm,(

.2 Root diameter (cm), measured using a measuring tape after removing the root hairs,

.3 Dry weight of the root (g), using a sensitive electronic balance after placing the roots, with root hairs removed, in perforated paper bags of known weight, and drying them in the air for two weeks until the weight stabilized .

Quality Traits :

Quality trait analyses, except for chlorophyll content (which was measured in the field using a portable SPAD device), were performed in the laboratories of the Ministry of Science and Technology / Biochemical and Clinical Chemistry Laboratory, Iraq / Baghdad. The quality traits included:

.1 Chlorophyll content (SPAD units), measured using the portable SPAD device, Soil-Plant Analyses Development (502.(

.2 Estimation of root protein content (%) using the Kjeldahl method [34.[

.3 Estimation of total carbohydrates in the root (%) based on [13.[

.4 Estimation of vitamins content (B1, B2, B3, B5, B6, C, E and folic acid) in the root (gµ) using High-Performance Liquid Chromatography (HPLC), as described by [18.[

.5 Estimation of nutrient content (N, P, K)% and (Fe, Mg, Zn) µg in the leaves. Plant samples were digested using the wet digestion method after drying and grinding them well with an electric mill, according to[5]. The concentrations of the samples were extracted and their absorbance read using an Atomic Absorption Spectrophotometer (SHIMADZU AA 7000) based on the calibration curve .

Statistical Analysis :

The experiment was designed according to the Randomized Complete Block Design (R.C.B.D), and statistical analysis was performed using Analysis of Variance (ANOVA) with the SPSS software. The means

were compared using Duncan's Multiple Range Test at a 5% significance level [9.[

Results and Discussion

Vegetative Traits :

Number of Leaves (Leaves per Plant), Leaf Area (cm²), and Dry Weight of Leaves (g :(

The results in Table (2) indicated significant differences between the values of the number of leaves, leaf area, and dry weight of the vegetative parts among the studied radish varieties. It is also evident from the results that the black radish variety performed best, recording the highest values for these traits with values of 12.66 leaves per plant, 5111.73 cm² for leaf area, and 27.52 g for dry weight of the vegetative parts, respectively. It was followed by the white radish variety and then the red radish variety. On the other hand, the watermelon radish variety recorded the lowest values for the studied traits, with 8.66 leaves per plant, 1447.90 cm² for leaf area, and 5.76 g for dry weight of the vegetative parts.

The observed differences in the means between the radish varieties could be attributed to the genetic composition differences among the studied varieties, which resulted in variations in the number of leaves, leaf area, and consequently the dry weight of the vegetative parts. Some traits, such as the number of leaves, leaf area, and root length, are controlled by genetic factors and are less affected by environmental conditions [14]. The reason for the lower values for the watermelon radish variety may be related to the unsuitable climatic conditions and soil type for this variety, which grows well in low temperatures ranging from 10 to 15°C and does not form roots in hot weather. Radish plants grown at the appropriate planting time show noticeable superiority in terms of growth and productivity. Watermelon radish grows better and has higher productivity in soils with medium texture, loose structure, and rich in organic matter [6.[

Table 2: Differences Between Radish Varieties in Number of Leaves (Leaves per Plant), Leaf Area (cm²), and Dry Weight of Shoot (g

Vegetative traits / Varieties	number of leaves (Leaf.Plant-1)	Leaf area (Cm_2)	Dry weight of shoots (g)
Red radish	10.666 b	3723.933 b	15.733 b
Watermelon radish	8.666 c	1447.900 c	5.766 c
White radish	11.666 b	3874.200 b	25.300 a
Black radish	12.666a	5111.733a	27.523a

*The similar letters indicate no significant differences at the 5% probability level according to Duncan's test.

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Productive Traits :

Root Length (cm), Root Diameter (cm), and Dry Root Weight (g:(

The results in Table (3) show significant differences in the root length, root diameter, and dry root weight among the studied radish varieties (red, white, watermelon, and black). The black radish variety recorded the highest mean for root length, which was 9.333 cm, followed by the white radish and then the red radish. The watermelon radish variety recorded the lowest mean for this trait, which was 4.466 cm.

The results also show that the red radish variety outperformed the other varieties in terms of root diameter and dry root weight, with values of 24.066 cm and 11.100 g, respectively. This was followed by the white radish and black radish for root diameter, and black radish and white radish for dry root weight. The watermelon radish recorded the lowest values for these traits, with 8.866 cm for root diameter and 2.233 g for dry root weight.

The differences observed between the radish varieties for these traits can be attributed to the correlation between root length, diameter, and dry weight with the number of leaves and leaf area in these varieties. The photosynthesis process is more efficient in varieties that have more leaves and a larger leaf area, leading to higher photosynthetic outputs, which, in turn, affect the root size and dry weight in the studied radish varieties [28, 10.[

This was confirmed by [2], who stated that there is a positive correlation between vegetative and productive traits in different radish plant varieties.

Table 3: Differences between the studied radish varieties in the root length (cm), root diameter (cm), and dry root weight (g

Productive qualities / Varieties	Root length (cm)	Root diameter (cm)	Root dry weight (g)
Red radish	8.1333 b	24.066 a	11.100 a
Watermelon radish	4.466 c	8.866 c	2.233 b
White radish	8.233 b	22.833 a	10.000 a
Black radish	9.333 a	17.633 b	10.833a

* The similar letters indicate no significant differences at the 5% probability level according to Duncan's test.

Quality Traits : Chlorophyll Index (SPAD unit), Protein Content (%), and Carbohydrates:(%)

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The results presented in Table (4) show significant differences among the radish varieties for chlorophyll index, protein content, and carbohydrate content in the root. The results indicate that the black radish variety outperformed the others by recording the highest mean values for chlorophyll index, root protein content, and root carbohydrate content, with values of 57.800 SPAD unit, 1.246%, and 4.360%, respectively. This was followed by the watermelon radish and white radish, and then the red radish for chlorophyll index. The lowest mean for this trait was recorded by the red radish variety, with a value of 50.900 SPAD unit.

Further analysis of the results in the same table shows that the varieties with the highest mean values for root protein content and carbohydrate content, after the black radish, were the white radish and watermelon radish, respectively. The lowest values for these traits were observed in the red radish variety, with 0.870% for root protein content and 3.223% for root carbohydrate content.

The variation between the radish varieties in chlorophyll index can be attributed to genetic differences among the varieties . The black radish variety is characterized by having the highest content of nitrogen and magnesium (Table 6), which contribute to higher chlorophyll content, as both nitrogen and magnesium are essential components of the chlorophyll molecule. Additionally, the black radish has more leaves and a larger leaf area (Table 2), which positively impacts its photosynthetic efficiency and allows it to synthesize larger amounts of protein and carbohydrates [36.[

Table 4: Differences between the studied radish varieties in the chlorophyll index (SPAD unit), protein content %

Physiological traits / Varieties	Chlorophyll SPAD unit	Protein%	Carbohydrate%
Red radish	50.900b	0.870 c	3.223 d
Watermelon radish	51.933 b	1.063 c	3.846 c
White radish	51.400 b	1.133 b	4.010 b
Black radish	57.800 a	1.246 a	4.360a

*The similar letters indicate no significant differences at the 5% probability level according to Duncan's test.

Vitamins (µg :(

The results presented in Table (5) show significant differences among the radish varieties for the mean content of vitamin B, C, E, and folic acid. It is evident from the results that the black radish variety outperformed the other varieties, recording the highest values for all types of vitamins, with values of 0.226, 0.353, 4.590, 1.166, 1.133, 227.933, 0.306, and 0.490 µg for B1, B2, B3, B5, B6, vitamin

C, vitamin E, and folic acid, respectively. This was followed by the white radish, then the watermelon radish, while the red radish recorded the lowest mean values for root vitamin content, with values of 0.110, 0.250, 3.856, 0.930, 0.723, 143.100, 0.133, and 0.323 µg for B1, B2, B3, B5, B6, vitamin C, vitamin E, and folic acid, respectively.

This variation in vitamin content among the four radish varieties, with the black radish surpassing the others, can be attributed to the physiological processes and biochemical interactions within the plant [32], which are influenced by various factors, including genetic and environmental factors [7]. Vitamins are secondary metabolic compounds that increase with the production of primary metabolic compounds as accompanying substances [22]. The superiority of the black radish in vegetative traits (Table 2), its nitrogen and magnesium content (Table 6), and its chlorophyll content in leaves (Table 4) contributed to an increased photosynthetic efficiency, which in turn led to a higher production of carbohydrates and proteins—primary metabolic products—resulting in an increase in accompanying secondary metabolites, such as vitamins.

The lower vitamin content observed in the red radish roots, compared to the other varieties, may be due to the lower nitrogen content (Table 6). Nitrogen plays a crucial role in the synthesis of amino acids, which are precursors for vitamin production [24.[

Table 5: Differences among the studied radish varieties in the content of vitamin B, C, E, and folic acid (µg

Vitamins / Varieties	B1	B2	B3	B5	B6	C	E	Folic acid
Red radish	0.110c	0.250b	3.856 c	0.930d	0.723 d	143.100d	0.133d	0.323d
Watermelon radish	0.130c	0.250b	4.200 c	1.006c	0.863 c	167.533c	0.180c	0.373 c
White radish	0.160b	0.276b	4.373 b	1.053b	0.910 b	178.900b	0.210b	0.423 b
Black radish	0.226a	0.353a	4.590 a	1.166a	1.133 a	227.933a	0.306a	0.490a

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*The similar letters indicate no significant differences at the 5% probability level according to Duncan's test.

Nutrient Elements (N, P, K)% and (Fe, Mg, Zn) µg :

The results in Table (6) indicate significant differences among the studied radish varieties regarding the content of nitrogen, phosphorus, potassium, magnesium, iron, and zinc in their leaves. It is clear from the table that the black radish outperformed the other three varieties,

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recording the highest mean values of 0.199% for nitrogen, 0.396% for phosphorus, 2.946% for potassium, 93.866 µg for magnesium, 4.733 µg for iron, and 9.366 µg for zinc. This was followed by the white radish and then the watermelon radish. Meanwhile, the red radish recorded the lowest mean values for the nutrient content in its leaves, with 0.139% for nitrogen, 0.256% for phosphorus, 2.130% for potassium, 81.300 µg for magnesium, 4.270 µg for iron, and 8.290 µg for zinc.

The differences observed in the nutrient content of the radish varieties can be attributed to the genetic variation among the varieties, as suggested by [2]. Genetic factors are crucial in controlling the absorption and accumulation of nutrient elements within the plant. Additionally, variations in the response of different varieties to fertilization programs may also contribute to these differences [33.[

Table 6: Differences among the studied radish varieties in the content of nitrogen, phosphorus, potassium (%), magnesium, iron, and zinc (µg) in their leaves

Nutrient concentration / Varieties	N	P	K	Mg	Fe	Zn
Red radish	0.139 c	0.256 d	2.130 d	81.300d	4.270d	8.290d
Watermelon radish	0.176 b	0.300 c	2.473 c	85.133c	4.380c	8.700c
White radish	0.181b	0.363 b	2.630 b	87.866b	4.533b	9.063b
Black radish	0.199a	0.396 a	2.946 a	93.866a	4.733a	9.366a

*The similar letters indicate no significant differences at the 5% probability level according to Duncan's test.

Conclusion:

Based on the results obtained, it can be concluded that black radish is a promising new variety that can be successfully cultivated under the region's environmental conditions. It demonstrated clear superiority in vegetative and physiological traits compared to the other studied varieties. White radish can also be grown under the same conditions; however, its productivity was lower than that of black radish. Red radish excelled in productivity traits, recording the highest values in this regard, while white radish was the most preferred by Iraqi consumers regardless of its nutritional content, due to local market preferences. In contrast, watermelon radish recorded the lowest average values in both vegetative and productivity traits among the studied varieties, indicating limited suitability for cultivation under these conditions.

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References

-1 Al–Juboori, A. A., Al-hamdani, S., and Hamdon, M. (2019). Effect of sowing date on growth and yield of four radish (Raphanus sativus L.) varieties. Mesopotamia Journal of Agriculture, 47(2), 96-103.

-2 Al-Hamadany, S. Y. H., Al-Jubouri, A. A. H., and Al-Shakarchy, W. Y. R. (2023). Variability and Expectant Genetic Advance for Yield and its Components in Radish (Raphanus sativus L.). In IOP Conference Series: Earth and Environmental Science (Vol. 1213, No. 1, p. .012018). IOP Publishing.

-3 APHA (American Public Health Association), (2017), Standard Methods for the Examination of Water and Wastewater 23h Edition, 800 1 Street, NW. Washington DC, USA .

-4 Aziz, F. M., and Hassan, D. H. (2020). Radish Juice Promote Kidney Stone Deposition in Ethylene Glycol-induced Urolithiasis in Rats. Cihan University-Erbil Scientific Journal, 4(1), 57-61.

-5 Baird, R., and Bridgewater, L. (2017). APHA, Standard Methods for the Examination of Water and Wastewater 23th Edition . American Public Health Association, Washington.

-6 Beinșan, C., and Mihuț, C. (2015). Research on the culture in a different variety radish chernozem from vertic Giarmata, Timis County.

-7 Biondi, F., Balducci, F., Capocasa, F., Visciglio, M., Mei, E., Vagnoni, M.,... and Mazzoni, L. (2021). Environmental conditions and agronomical factors influencing the levels of phytochemicals in Brassica vegetables responsible for nutritional and sensorial properties. Applied Sciences, 11(4), 1927,10-11.

-8 Biharee, A., Chaudhari, L., Bhartiya, S., Kori, S. K., Chaudhary, A., Dubey, D., and Yadav, A. (2024). A Comprehensive Study on Natural Products and their Bioactive Constituents to Cure Respiratory Diseases. The Natural Products Journal, 14(2), 32-70.

-9Duncan, D. B. (1955). Multiple range and multiple F . tests. biometrics, 11(1), 1-42.

-10Esho, K. B., and Jasim, E. A. A. (2022). Correlation And Path Coefficient Analysis And Regression In Radish (Raphanus Sativus L.). Int. J. Agricult. Stat. Sci. Vol, .18(1), 1199-1205.

-11Gutiérrez, R. M. P., and Perez, R. L. (2004). Raphanus sativus (Radish): their chemistry and biology. The scientific world journal, 4(1), 811-837.

-12 Hamdon, M. M., Al-hamdani, S. Y., and Al–juboori, A. A. (2019). Effect of sowing date on growth and yield of four radish (Raphanus sativus L.) varieties. Mesopotamia Journal of Agriculture, 47(2) 12-23.

-13Hedge, J. E., Hofreiter, B. T., and Whistler, R. L. (1962). Carbohydrate chemistry. Academic Press, New York, 17, 371-80.

-14Jakhwal, R., Goswami, G., Pant, S. C., Kumar, V., Bahuguna, P., and Verma, S. (2022). Studies on variability, heritability, genetic advance in radish (Raphanus Sativus L.) for root yield and quality traits under mid-hills of uttarakhand. Progressive Agriculture, 22(1), 69-73 .

-15Jeon, H., Oh, S., Kum, E., Seo, S., Park, Y., and Kim, G. (2022). Immunomodulatory effects of an aqueous

extract of black radish on mouse macrophages via the TLR2/4-mediated signaling pathway. Pharmaceuticals, 15(11), 1376,44-53.

-16Kanash, L. (2023). Comparative study of some introduced radish cultivars in terms of growth and yield. Al-Baath University Journal - Series of Agricultural Sciences and Biotechnology, 45(2),122-130.

-17Kim, Y. S., Lee, J. J., Kim, I., Yu, D., and Ha, J. H. (2022). Physicochemical and storage characteristics of pork Tteokgalbi treated with watermelon radish powder. Applied Sciences, 12(17), 86-94.

-18Kozhanova, L. A., Fedorova, G. A., and Baram, G. I. (2000). Determination of water- and fat-soluble vitamins in multivitamin preparations by high-performance liquid chromatography. Journal of Analytical Chemistry, 57, 40-45.

-19Kurina, A. B., Kornyukhin, D. L., Solovyeva, A. E., and Artemyeva, A. M. (2021). Genetic diversity of phenotypic and biochemical traits in VIR radish (Raphanus sativus L.) germplasm collection. Plants, 10(9), 1799.

-20Lee, J. J., Jeong, E., and Park, Y. J. (2021). Quality characteristics and antioxidant activity of Yanggaeng added with watermelon radish flesh powder. Korean J Food Nutr, 34, 631-640.

-21Mahmoud, S. H., Salama, D. M., El-Tanahy, A. M., and Abd El-Samad, E. H. (2019). Utilization of seaweed (Sargassum vulgare) extract to enhance growth, yield and nutritional quality of red radish plants. Annals of Agricultural Sciences, 64(2), 167-175.

-22Mahmudiono, T., and Haliman, C. D. (2023). B Vitamins. In Handbook of Food Bioactive Ingredients: Properties an Applications (pp. 1-31). Cham: Springer International Publishing.

-23Matar, R. A. M. (2021). Response of growth, yield, and content of black radish Raphanus sativus var. niger to sulforaphane and methyl jasmonate under organic and chemical fertilization. Master's Thesis, College of Agriculture, University of Diyala, pp. 1-5.

-24Miret, J. A., and Munné-Bosch, S. (2014). Plant amino acid-derived vitamins: biosynthesis and function. Amino Acids, 46, 809-824 .

-25 Mitsui, Y. (2017). Gene expression profiles during tuberous root development. The Radish Genome, 109-119.

-26 Noman, O. M., Nasr, F. A., Alqahtani, A. S., Al-Zharani, M., Cordero, M. A. W., Alotaibi, A. A., ... and Daoud, A. (2021). Comparative study of antioxidant and anticancer activities and HPTLC quantification of rutin in white radish (Raphanus sativus L.) leaves and root extracts grown in Saudi Arabia. Open Chemistry, 19(1), 408-416.

-27 Park, C. H., Ki, W., Kim, N. S., Park, S. Y., Kim, J. K., and Park, S. U. (2022). Metabolic profiling of white and green radish cultivars (Raphanus sativus). Horticulturae, 8(4), 310.

-28 Rodríguez-Larramendi, L. A., Hernández, F. G., La O-Arias, M. A., Reyes-Muro, L., Campos-Saldaña, R. A., and Salas-Marina, M. Á. (2020). Leaf growth and biomass accumulation in radish inoculated with rhizosphere microorganisms: Leaf growth and biomass accumulation in radish. Revista de la . Facultad de Ciencias Agrarias UNCuyo, 52(2), 78-87.

ISSN 2072-3857

-29 Selvakumar, R. (2022). An update on radish breeding strategies: an overview. Case Studies of Breeding Strategies in Major Plant Species .

-30 Shirasawa, K., Hirakawa, H., Fukino, N., Kitashiba, H., and Isobe, S. (2020). Genome sequence analysis of a giant-rooted 'Sakurajima daikon'radish (Raphanus sativus). bioRxiv, 2020-02.

-31 Singh, A., Sharma, S., and Dolly. (2020). Radish. Antioxidants in Vegetables and Nuts-Properties and Health Benefits. Springer, Singapore. 209-235.

-32Singh, B. K. (2021). Radish (Raphanus sativus L.): Breeding for higher yield, better quality and wider adaptability. Advances in Plant Breeding Strategies: Vegetable Crops: Volume 8: Bulbs, Roots and Tubers. Springer, Cham. 275-304 .

-33Vallejo, F., Tomás- Barberán, F. A., and García- Viguera, C. (2002). Potential bioactive compounds in health promotion from broccoli cultivars grown in Spain. Journal of the Science of Food and Agriculture, 82(11), 1293-1297.

-34Van Dijk, D., and Houba, V. J. G. (2000). Homogeneity and stability of materials distributed within the Wageningen evaluating programmes for analytical laboratories. Communications in soil science and plant analysis, 31(11-14), 1745-1756.

-35Wallace, D. H., & Monger, H. M. (1965). Studies of the physiological basis for yield differences. I. Growth analysis of six dry bean varieties,Crop Sciences, 5, 343-348.

-36Yousaf, M., Bashir, S., Raza, H., Shah, A. N., Iqbal, J., Arif, M., ... and Hu, C. (2021). Role of nitrogen and magnesium for growth, yield and nutritional quality of radish. Saudi Journal of Biological Sciences, 28(5), 3021-3030.

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