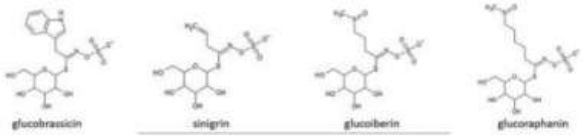
edible leaves all winter. In addition, some cultivars can be planted in spring and harvest occurs during summer and autumn. Therefore, fresh kale is available on the market all year round.

Phytochemistry of Kale

HPLC analysis revealed 14 glucosinolates, 20 anthocyanins, 3 phenylpropanoids, and 6 carotenoids in the kale. This finding supports the fact that kale, like other major brassicas have major phytochemicals belonging to the glucosinolates, polyphenols and carotenoids groups with health benefits.



National and international organization working on Kale improvement programme

National Institutes (India)
ICAR–Central Institute of Temperate Horticulture (CITH), Srinagar – Focuses on temperate vegetable crops like kale, cabbage, and broccoli for varietal evaluation and adaptation.
ICAR–Indian Agricultural Research Institute (IARI), New Delhi – Conducts research on crop genetics, pre-breeding, and physiological studies of Brassica species.
ICAR–Indian Institute of Vegetable Research (IIVR), Varanasi – Works on genetic improvement, varietal development, and germplasm collection of cole crops including kale.
International Organization
The World Vegetable Center (WorldVeg), Taiwan
John Innes Centre, United Kingdom
Rothamsted Research, United Kingdom
USDA–Agricultural Research Service (USA)
European Cooperative Programme for Plant Genetic Resources (ECPGR)
CGIAR Centres (e.g., Bioversity International and CIP) – Support global germplasm conservation and pre-breeding including kale.

Malik *et al* (2024) Genetic diversity, population structure and marker-trait associations in Indian kale (*Brassica oleracea* L. gp. acephala) using cross-species microsatellite markers *Heliyon* 10 (8) https://doi.org/10.1016/j.heliyon.2024.e29521

Pre-breeding, breeding and future improvement programmes in kale

Kale breeding primarily aims to enhance yield, nutritional quality, and resistance to biotic and abiotic stresses. Germplasm studies have revealed wide genetic and morphological diversity within and across regional collections, providing a strong foundation for selection and improvement (Malik *et al* 2024). Pre-breeding efforts focus on tapping useful alleles from wild *Brassica* relatives and landraces to broaden the genetic base. Interspecific hybridization and introgression are widely used to introduce disease and pest resistance traits. Modern programmes integrate genomic tools such as reference genomes, GWAS, and transcriptomics to accelerate trait discovery and marker development. Marker-assisted selection (MAS), genomic selection, and high-throughput phenotyping are being applied for both simple and complex traits like yield, quality, and stress tolerance. Breeding strategies also target enhanced phytochemical content such as glucosinolates, carotenoids, and phenolics—to improve kale's nutraceutical value. Conservation and characterization of wild and local germplasm remain essential for long-term improvement. Integrated pest and disease management, along with adaptation trials under agroecological and organic systems, guide the development of climate-resilient cultivars. Future approaches emphasize multi-trait genomic selection, speed breeding, and global collaboration through open databases and public–private partnerships to deliver high-yielding, nutrient-rich, and sustainable kale varieties.

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भाकृअनुप
ICAR

Kale: From Wild Origins to Modern Greens – Evolution, Diversity & Pre-Breeding Insights

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Introduction

Kale (*Brassica oleracea* var. *acephala;* Family: Brassicaceae; Chromosome no; 2n=2x=18) is a cruciferous vegetable, characterized by leaves along the stem and belongs to non-heading brassica group. Which, in recent years, have gained a great popularity as a superfood. Consequently, in a popular culture it is listed in many lists of the healthiest vegetables. Kale, commonly known as a functional food/superfood due to rich in protein (4.28g), total lipids (0.93g), minerals like Fe (1.47g), Mg (47g) and K (491g), Vitamins-C (120mg) highest in comparison with all brassica crops. Biological activity includes antioxidant activity, anticancerogenic activity and effects on gastrointestinal tract. Kale thrives best in cool and moist climatic conditions. It is a hardy leafy vegetable that can tolerate light frost and low temperatures (5°C to 10°C) better than most other cole crops. grows in various soil types but performs best in deep, loamy soils with good drainage and aeration, having a near-neutral pH of 6.0–6.5. The best growing season is autumn and winter in temperate regions, and the *rabi* season in subtropical areas. This crop prefers full sunlight but can also tolerate partial shade. It grows well under moderate rainfall with adequate soil moisture during the early growth stages. The crop has become very popular in the Kashmir, Himachal Pradesh, Uttarakhand, Ladakh and Arunachal Pradesh as well as in many metropolitan cities of India.

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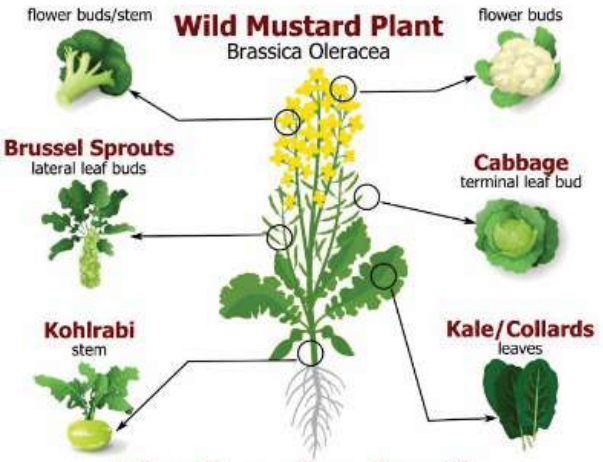
Taxonomy

Brassicaceae family has very complex taxonomy and systematics. The Brassicaceae family belongs to order brassicales and by recent findings have 341 genera and 3977 species. Modern brassica crops including kale are derived from these species through early selection of crop varieties in Mediterranean area.

Origin and evaluation of brassicas

The *B. oleracea* primitive ancestors were under cultivation for several millennia, and written evidence are available since ancient Greek and Roman times. These long-lasting human mediated selections resulted in significant morphological diversity of plant organs that are specific for particular Brassicas.



Among these groups, *acephala* group includes leafy, non-heading cabbages with common names: kale and collards. These names occur in different ways in many languages. Kale is often called 'borecole'.

Different morphologically variable varieties of Kale available across the world

(Source; European Cooperative Program for Crop Genetic Resources (http://ecpgr.cgn.wur.nl/Brasedb)

Common name	Botanical name
Kale	*B. oleracea* L. var. *acephala* DC.
Scotch kale	*B. oleracea* L. *convar. acephala* (DC.) Alef. *var. sabellica* L.
Collard	*B. oleracea* L. var. *viridis* L
Palm kale	*B.oleracea L. convar. acephala (DC.) Alef. var. palmifolia L*
Marrow stem kale	*B. oleracea L.var. acephala (DC.) Alef. var. medullosa L.),*
Thousand head kale	*B. oleracea L. var. ramosa DC*
Portuguese Tronchuda Cabbage	*B. oleracea L. var. costata DC*
Siberian kale (Hybridization product of *Brassica oleracea* L. var. *acephala* and *Brassica rapa* L.)	*Brassica napus L. var. pabularia*

Other eating kale different types: Winterbor Kale, Lacinato Kale, Scarlet Kale, Red Russian Kale, RedBor Kale, Beira Kale, Darkibor Kale, Walking Stick Kale, Japanese Flowering Kale.

There is a large number of kale populations/landraces across world. This variability may have resulted from intrapopulation variability generated by cross-pollination of plants, and as inter-population variability resulting from farmer's selection and adaptations to local ecological conditions.

Figure: Leafy green and red kale, *Brassica oleracea var. acephala* L. growing in ICAR-CITH, Srinagar, Kashmir, India.

In warmer climate, seedlings are normally planted by summer end or early autumn. Cultivars with higher frost hardiness and resistance to premature bolting after induced vernalization by low temperatures produce