

Performance evaluation of lettuce (*Lactuca sativa* L.) growth, yield and quality under subtropical climate



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Summary

Lettuce (*Lactuca sativa* L.) belongs to the family Asteraceae and is known as a leafy salad vegetable. It is rich in vitamins like Vitamin A and C, and also a good source of minerals such as iron, sodium, calcium etc. It is more popular in temperate regions and also performing well under subtropical climatic conditions during the winter season. Therefore, the present investigation was carried out to identify the suitable variety of lettuce for higher yield and quality under subtropical climate. The experiment was conducted with five treatments replicated thrice. Seeds of these five lettuce varieties viz., Tango, Bingo, Summer Star, Grand Rapid and Black Rose were sown in pottrays prefilled with a combination of media made of coco peat, vermiculite and perlite in the ratio 3:1:1. After thirty days plants were plugged out and transplanted under field condition to study the performance of lettuce varieties. Among the studied varieties, the maximum yield (191.44 q/ha) was recorded with the variety Summer Star which was at par (190.32 q/ha) with the Bingo variety, followed by (129.50 q/ha) in Tango and the least (85.51 q/ha) by Black Rose. However, vitamin C content and total carotenoid content were significantly found highest (15.98 mg/ 100 g) and 8.06 mg/ 100 g in the Black Rose variety, respectively. Tango variety observed maximum chlorophyll 'a' (5.85 mg/ g FW), 'b' (2.01 mg/ g FW) and total chlorophyll (7.85 mg/ g FW) content among studied lettuce varieties.

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Introduction

Lettuce (*Lactuca sativa* L.) is popular as a leafy salad vegetable world-wide and has the largest area and production in comparison to other salad crops in the world. It is considered an annual herbaceous plant that can grow up to 20-30 cm in height. It is mostly consumed raw as salad and also cooked as a vegetable. Lettuce is generally produced a larger scale in several countries and is also grown as large scale in kitchen/ home gardens (Kristkova et al. 2008)¹. It is a cool-season crop cultivated in colder climates but also easily cultivated in subtropical regions during winter months from November to February. High temperature is one of the main abiotic stresses that affects the physiological, morphological and biochemical traits of lettuce plants (Rezaei et al. 2015; Al-Said et al. 2018; Mathur et al. 2018a)^{2,3,4}. It is one of the most demanded salad crops

worldwide in the form of fresh as well as ready-to-use markets and generally has low calory, fat and sodium content (Islam et al. 2021)⁵. In India area of lettuce (*Lactuca sativa* L.) crop increased significantly because of changes in the food habits of the society and its medicinal and nutritional properties. It is a most important dietary vegetable and is consumed fresh as salads. Various varieties of lettuce are different in shape, structure, chemical composition, marketable qualities, range of adaptable climatic conditions, hardiness, and yield performance. It can be easily cultivated around the year using suitable cultivars under different environmental conditions to meet nutritional requirements (Islam et al. 2021; Leon et al. 2012)^{5,6}.

Now-a-days, the demand for lettuce has increased significantly in the country because of its nutritive value, medicinal properties and change in the food habits of the society. It is a rich source of vitamin A and minerals like calcium, iron, magnesium, potassium and sodium. It is also known for its anti-inflammatory, sedative, diuretic, expectorant, anti-diabetic, cholesterol-lowering, reducing body weight and the risk of cardiovascular diseases, promoting brain health (Yakoot et al. 2011)⁷. Several varieties of lettuce are grown in subtropical conditions in India during winter months in open or greenhouses, or hydroponics systems. It can be easily cultivated in all types of soil, but it grows well and gives high returns in silt-loam and sandy soils because these types of soils provide better drainage and heat more easily during the day and which is exclusively important in cooler months

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of the growing season (Kristkova et al. 2008)¹. Lettuce varieties are thermo-sensitive, and bolting occurs with fluctuation of temperature. There is little published information available on how individual varieties perform in open field condition hydroponic systems under greenhouses. Varietal screenings in warmer western climates looked at high-temperature tolerance and stress recovery to improve yield (Han et al. 2016)⁸. It is popular in the winter season in subtropical areas of India and fetches a good price to the growers in metropolitan cities. The productivity of lettuce is quite low in India (6.33 t/ha) as compared to the world average (21.89 t/ha) (Anonymous 2011)⁹, which is a major concern for the growers. Therefore, it is the need of the hour to identify and select suitable lettuce varieties for commercial cultivation in subtropical climates which give maximum quality yield. India imports lettuce to fulfil the demand in metropolitan cities like Mumbai and Delhi. In recent years, greenhouses have started to expand their cultivation techniques, which include soilless cultivation technology like aeroponics in addition to conventional soil cultivation (Koukounaras 2021)¹⁰. Plants are cultivated in the system by misting the nutrient solution. Additionally, the system has the potential to reuse nutrients and water, reduce the effects of climatic changes, increase production efficiency, and reduce the occurrence of pests and soil-borne diseases (Gashgari et al. 2018)¹¹. However; soilless cultivation can be effectively improved and utilized as an alternative choice for growing healthy food plants such as Lettuce and other herbs.

The present research experiment was carried out in open field conditions at ICAR-Central Institute for Subtropical Horticulture, Lucknow, Uttar Pradesh, India, with the objective of identifying and evaluating the suitability of cultivation and selecting the most suitable lettuce variety for commercial cultivation and better economic return when grown in subtropical climate during winter months.

Materials and Methods

Experimental site and weather condition

To identify the suitable lettuce variety for higher yield and quality under subtropical climate, the experiment was conducted at the Rehmankhara Experimental Farm of the ICAR-Central Institute for Subtropical Horticulture, Lucknow, Uttar Pradesh during 2021–2022. The experimental site is situated at 26° 45' to 27° 10' N latitude, 80° 30' to 80° 5' E longitude and 123 m above sea level. The subtropical environment and weather of the experiment's site are characterized by hot, dry summers and cool, dry winters. Southwest monsoon comes during the July to September months. The average maximum temperature presented during the month of May-June is approximately between 40 °C - 45 °C, while the maximum and minimum temperatures recorded between November to February (20 °C – 27°C) and (3 °C – 11°C), respectively; whereas the maximum relative humidity ranged from 85% - 92% and minimum relative humidity varied from 60% – 64%, respectively during cropping season (Fig 1.).

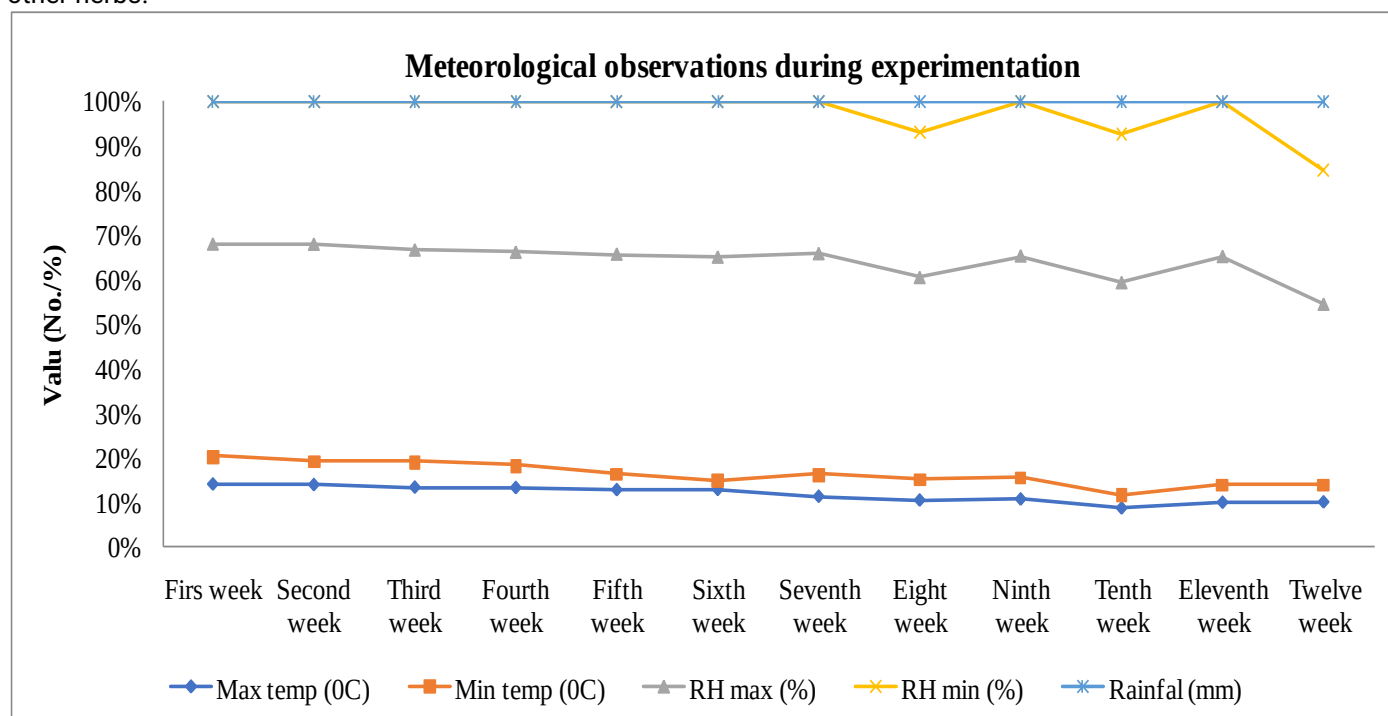


Figure 1. Mean weekly weather data from November, 2021 to February, 2022

Plant material and media composition

In the first week of October 2021, lettuce seeds of the five cultivars such as Tango, Summer Star, Grand Rapid, Bingo, and Black Rose kinds were sown in portrays already filled with a media mixture made of coco peat,

vermiculite, and perlite in the ratio 3:1:1, respectively and sterilised it with hydrogen peroxide @ 0.02%.

Experimentation

After 30 days of seed sowing, seedlings of lettuce having 4–5 leaves were transplanted to an experimental place in open field conditions (Fig. 2). Twenty-five plants were kept under each treatment/variety. Plot size was 2 x 2

metre. Uniform cultural practices were followed during experimentation on five studied lettuce varieties. Ten plants from each lettuce variety at horticultural maturity were harvested and washed with fresh water and growth parameters were calculated like plant height (cm), plant weight (g), plant stem diameter (mm), root length (cm), number of leaf/ plant, plant shoot weight (g), leaf length (cm), leaf width (cm), leaf weight (g), root weight (g), leaf index and yield (q/ha). Quality parameters such as vitamin C (ascorbic acid) were determined based on the 2-6- dichlorophenol – indophenol visual titration method using a formula suggested by AOAC, (1996)¹² and expressed in mg/100g, total carotenoids content of leaves was determined as method suggested by Kemmerer and Frap, (1943)¹³ and expressed in mg/100g, dry matter content (%) was determined by using the formula: Dry Matter = oven dry weight / Fresh sample weight x 100 AOAC (2005)¹⁴, chlorophyll 'a', chlorophyll 'b' and total chlorophyll content were determined by using under the given formula and expressed in mg/g fresh weight-

Chlorophyll 'a' = $(9.93 \times \text{OD at } 660\text{nm}) - (0.777 \times \text{OD at } 642.5\text{nm})$

Chlorophyll 'b' = $(17.6 \times \text{OD at } 642.5\text{nm}) - (2.81 \times \text{OD at } 660\text{nm})$

Total chlorophyll = $(7.12 \times \text{OD at } 660\text{ nm}) + (16.8 \times \text{OD at } 642.5\text{nm})$

Statistical analysis



Figure 2. Experimental site and field view of lettuce experiment

The experiment was conducted in a Randomized Block Design having five treatments (variety) with three replications, and data were analyzed using software developed by Sheoran et al. (1998)¹⁵. The results have been interpreted on the basis of significance at 5 per cent level. Means SE were used to express the results.

Results and Discussion

The results of the present experiments obtained from the study have been tried to interpret the treatment effects on various growth and quality characteristics of lettuce for identifying suitable varieties for cultivation in subtropical climates. Significant variations (except dry matter content) were found among studied lettuce varieties with respect to plant height, plant weight, plant

stem diameter, root length, number of leaves, plant shoot weight, leaf length, leaf width, leaf weight, root weight, leaf index, yield, vitamin C, total carotenoids, chlorophyll 'a', chlorophyll 'b' and total chlorophyll.

Lettuce growth, morphometric parameters and yield

Lettuce varieties showed (Tables 1, 2 and 3) significant variation with respect to growth, yield and quality parameters except dry matter content, where non-significant variation was recorded. Table 1 clearly indicates the significant variation among five lettuce varieties regarding plant height, plant weight, number of leaves/ plants, total leaf weight, leaf length, leaf width, and leaf area index. The significant maximum plant height (25.70 cm), number of leaves/ plant (28.17), leaf length (21.37 cm) and leaf area index (0.89) were recorded in Tango variety while minimum plant height (21.43 cm), plant weight (177.83 g), leaf weight (162.50 g), leaf length (18.01 cm) and width (15.84 cm) were found in lettuce variety Black Rose. Bingo variety significantly yielded the highest plant weight (447.67 g) followed by Summer Star (433.83 g) and the least (177.83 g) in the variety Black Rose. Total leaf weight/ plant and leaf width were noted significantly maximum (393.17 g and 20.66 cm) in the variety Summer Star, followed by Bingo (382.17 g and 20.27 cm) and minimum (162.50 g and 15.84 cm) in the variety Black Rose, respectively.

Significant variations (Table 2) in stem weight, stem diameter, root length, root weight and yield were also observed among lettuce varieties. Significant highest stem weight (29.17 g) and stem diameter (16.49 cm), were recorded in the variety Summer Star followed by stem weight in Tango (21.33 g), which was at par with Bingo (21.17 g) and least (9.33 g and 11.59 cm) in variety Black Rose. A similar trend was also observed for root length and root weight; maximum (11.33 g) root weight was noticed in the variety Summer Star followed by Grand Rapid (9.33 g) and Bingo (9.33 g) and minimum (6.00 g) in Black Rose. The highest average root length (12.70 cm) was measured in Summer Star which was at par with Bingo (12.42 cm) variety followed by Grand Rapid (11.97 cm) and lowest in variety Black Rose (9.62 cm). Lettuce yield was recorded maximum (191.44 q/ha) in Summer Star which was at par (190.32 q/ha) with Bingo variety followed by (129.50 q/ha) in Tango and least (85.51 q/ha) by Black Rose. Table 2 shows that these parameters were found significantly maximum in Summer Star variety and minimum in Black Rose.

The plant growth characteristics for different treatments in lettuce showed significant differences. However, maximum plant height, number of leaf, length of leaf and leaf area index were recorded in Tango variety that might be due to the better genetic potential of the variety and also better photosynthetic machinery of the particular variety as depicted in Table 3. Our findings are also in conformity with the findings of Sapkota et al. (2019)¹⁶ on varietal variation in leaf length in lettuce; El-Helaly & Darwish (2019)¹⁷ on number of leaf in lettuce; Feltrim et al. (2009)¹⁸ on varietal differences on plant weight in lettuce; Lei & Engeseth (2021)¹⁹ on leaf length of lettuce; Kim et al. (1995)²⁰ on varietal variation in leaf

area index in lettuce crop and reported significant variation for these plant growth characteristics in their respective varietal evaluation trials. Stem, root and yield attributes were recorded significant variation among five studied lettuce varieties. Stem weight, stem diameter, root weight and root length, and yield were significantly noted maximum in variety Summer Star which might be due to genetic make of variety and also better root characteristics of the variety as compared to other varieties which has given better nutrient uptake to Summer Star variety as corroborated with the findings of Qiansheng et al. (2018)²¹ reported that root characteristics are more dependent on lettuce genotypes. Our results are also supported by the findings of Barbara & Monika (2021)²²; Atikah & Widyawati (2019)²³ who had reported significant effect of varieties of lettuce on stem weight; Ahooi et al. (2020)²⁴; Qiansheng et al. (2018)²¹ on stem diameter in lettuce; El-Helaly & Darwish (2019)¹⁷; Agarwal et al. (2019)²⁵ on root length; Thomas et al. (2021)²⁶; Omaye & Buchanan (2013)²⁷ for varietal difference on yield in lettuce crop.

Quality attributes of lettuce varieties

Quality parameters such as vitamin C, carotenoids, chlorophyll 'a', 'b' and total chlorophyll were significantly differ among five studied lettuce varieties except dry matter content (Table 3) which showed non-significant pattern among varieties. Vitamin C content was significantly found highest (15.98 mg/ 100 g) in variety Black Rose followed by (11.46 mg/ 100 g) in Summer Star and lowest (10.77 mg/ 100 g) in Tango variety. Likewise, maximum total carotenoids (8.06 mg/ 100 g)

were also noted in Black Rose among lettuce varieties followed by Tango (6.66 mg/ 100 g) and minimum in Summer Star variety (4.19 mg/ 100 g). Significantly highest total chlorophyll (7.85 mg/ g FW), chlorophyll 'a' (5.85 mg/ g FW) and chlorophyll 'b' content (2.01 mg/ g FW) were recorded in variety Tango and least chlorophyll 'a' (1.86 mg/ g FW), 'b' (0.22 mg/ g FW) and total chlorophyll (2.27 mg/ g FW) were found in variety Summer Star.

The lettuce varieties recorded non-significant difference on dry matter content. However variety Grand Rapid recorded maximum followed by Black Rose and least observed in Summer Star. Vitamin C and total carotenoids content were observed significant differences and Black Rose variety recorded maximum value. It might be due to genetic behaviour of particular variety, better light intensity and nutrient assimilation rate. The similar findings of vitamin C were also confirmed by Omaye & Buchanan (2013)²⁷ and De Souza et al. (2022)²⁸ for carotenoids and reported environmental effect on particular variety. The varieties observed significant effect on chlorophyll 'a', chlorophyll 'b' and total chlorophyll, however, Tango variety recorded maximum chlorophyll 'a', 'b' and total chlorophyll while minimum were found in Summer Star variety. It might be due to genetic potency of particular variety, higher light intensity, favourable plant growth characters and regular nutrient availability to plants. Our findings are also supported by the findings of Lei & Engeseth (2021)¹⁹ in lettuce for chlorophyll 'a' and 'b' content and El-Helaly & Darwish (2019)¹⁷ for total chlorophyll in lettuce crop.

Table 1. Performance of lettuce varieties with respect to plant growth characteristics

Name of variety	Average plant height (cm)	Average plant weight (g)	Number of leaf/ plant	Total leaf weight/ plant (g)	Average leaf length (cm)	Average leaf width (cm)	Leaf area index
Tango	25.70	292.50	28.17	264.17	21.37	16.88	0.89
Summer star	23.00	433.83	19.50	393.17	19.84	20.66	0.67
Grand Rapid	20.30	274.70	23.33	251.33	18.14	17.89	0.71
Bingo	22.18	447.67	23.17	382.17	21.17	20.27	0.73
Black Rose	21.43	177.83	20.67	162.50	18.01	15.84	0.79
C.D. at 5 %	2.903	22.155	2.577	9.513	2.617	2.388	0.106
SE(m)	0.877	6.69	0.778	2.873	0.79	0.721	0.032
SE(d)	1.24	9.461	1.101	4.062	1.117	1.02	0.045
C.V.	6.742	3.562	5.869	1.712	6.945	6.822	7.279

Table 2. Response of lettuce varieties on stem, root and yield attributes

Name of variety	Average stem weight (g)	Average stem diameter (cm)	Average root weight (g)	Average root length (cm)	Yield (q/ha)
Tango	21.33	14.47	6.83	11.28	129.50
Summer star	29.17	16.49	11.33	12.70	191.44
Grand Rapid	17.33	16.13	9.33	11.97	126.88
Bingo	21.17	14.59	9.33	12.42	190.32
Black Rose	9.33	11.59	6.00	9.62	85.51
C.D. at 5 %	2.538	1.31	2.926	1.257	9.123
SE(m)	0.766	0.396	0.883	0.38	2.755
SE(d)	1.084	0.559	1.249	0.537	3.896
C.V.	6.75	4.675	17.863	5.669	3.297

Table 3. Response of lettuce varieties on quality parameters

Name of variety	Vitamin C (mg/100 g)	Total carotenoids (mg/ 100 g)	Chlorophyll 'a' (mg/ g FW)	Chlorophyll 'b' (mg/ g FW)	Total chlorophyll (mg/ g FW)	Dry matter content (%)
Tango	10.77	6.66	5.85	2.01	7.85	6.87
Summer star	11.46	4.19	1.86	0.22	2.27	6.09
Grand Rapid	11.11	5.78	2.84	0.41	3.25	7.27
Bingo	11.11	5.97	3.28	0.75	4.42	6.77
Black Rose	15.98	8.06	3.57	0.74	4.31	6.97
C.D. at 5 %	1.64	0.30	0.29	0.18	0.32	N/A
SE(m)	0.496	0.091	0.09	0.054	0.097	0.23
SE(d)	0.702	0.129	0.127	0.077	0.138	0.326
C.V.	7.113	2.582	4.483	11.43	3.822	5.873

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Declaration of Interests

The authors have no conflict of interest to declare.

Data Sharing

All relevant data are within the manuscript.

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