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Research Article

Evaluation of exotic Lettuce (*Lactuca sativa* L.) genotypes for the growth & yield attributes under agro-ecological conditions of Tandojam

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ABSTRACT

Lettuce (*Lactuca sativa* L.) is a cool season green leafy vegetable belonging to the Composite family. It is very nutritious and a rich source of vitamin C, minerals and fiber and is commonly consumed in salad mixes. The field-based study was conducted during Winter 2023-24, at Experimental Area of Plant Breeding and Genetics Department, Sindh Agriculture University, Tandojam. following randomized complete block design. For present study three genotypes *viz:* green leaf lettuce, Italic Lettuce and Red Green Dragon Lettuce were used to evaluate their growth, yield and physiological traits. The substantial variation was observed for all the traits investigated. The maximum Chlorophyll Content (47.42 SPAD) was recorded in Red Green Dragon Lettuce variety, whereas the minimum chlorophyll content (30.54 SPAD) was recorded in Italic Lettuce. The maximum plant spreading (46.32 cm) was recorded in green leaf lettuce variety, whereas the minimum plant spreading (31.01 cm) was recorded in Red Green Dragon Lettuce variety. The green leaf lettuce variety showed maximum width of leaf (15.31 cm), whereas the minimum width of leaf (4.49 cm) was recorded in Red Green Dragon Lettuce variety. The Red Green Dragon Lettuce variety produced maximum Length of Leaves (24.55 cm), Plant Height (25.32 cm) and root depth (12.03 cm), whereas the minimum Length of Leaves (11.51 cm), Plant Height (12.46 cm) and Root Depth (9.87cm) was recorded in Italic Lettuce. The Maximum leaf yield was recorded in Green Leaf Lettuce followed by Red Green Dragon Lettuce. It is recommended that for obtaining higher leaf yield Green Leaf Lettuce may be grown under agro-ecological conditions of Tandojam.

Keywords: Exotic lettuce, lettuce genotypes, green leaf lettuce, Italic Lettuce, Red Green Dragon Lettuce.

INTRODUCTION

Lettuce (*Lactuca sativa L.*) is a highly valued salad crop and holds a prominent position among winter vegetables, thanks to its excellent economic returns, rich nutritional content, and significant production potential. It is cultivated as a salad crop in certain regions of Himachal Pradesh. The crop's popularity is increasing due to its versatile applications, preference among tourists and local consumers, and consistent demand in urban markets throughout the year. In temperate climates, lettuce grows as an annual plant, with its leaves ranging in color from light yellow-green to deep red. It is a vital dietary component, being rich in vitamin A and minerals such as calcium and iron. Notably, the nutrient concentration is greater in the darker green, outer leaves. Among the different types, leafy varieties have the

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main nutrient levels followed by butterhead and crisphead types. This improvement in quality is attributed to the higher exposure of green leaves to light. (Ryder, 1979).

Lettuce exhibits significant variation in traits such as leaf length, shape, color, texture, size, and heading type. These variations must be analyzed to identify superior genotypes. Lettuce is consumed both fresh and in processed forms. In India, lettuce cultivars typically have low average yields due to the prevalence of suboptimal cultivars or hybrids, the impact of biotic and abiotic stresses, genetic drift within cultivars, and the emergence of new pathogen races. To improve productivity, it is essential to restructure the genetic makeup of lettuce germplasm and develop or identify high-yielding varieties and hybrids (Ramesh et al., 2016).

The use of genetic resources to develop sustainable solutions for addressing fundamental challenges in major crops has been proposed repeatedly. However, these resources have not been fully utilized, primarily due to inherent issues such as their vast size and the insufficient evaluation and classification of their traits (Dahberg, 1995). The maintenance, evaluation, and characterization of germplasm for economically significant traits are essential steps in any crop improvement program. Genetic diversity in vegetable crops plays a crucial role in selecting superior genotypes to enhance yield. Both qualitative and quantitative traits can be selected in parental lines for hybridization to harness heterosis or identify desirable segregants in later generations. Understanding the relationships among various traits forms the foundation for selecting yield and its contributing factors during crop improvement efforts. As yield is a complex quantitative trait, simple correlation and regression analyses provide limited insight into the relationships between traits and yield. There are only a few studies available that focus on phenotypic variability, correlation, and path analysis in lettuce (Thakur et al., 1997; Meglic and Vozlic 2000; Kumar et al., 2010). Researchers, often uncertain about the relative significance of variables, tend to include all potential factors that might influence outcomes, resulting in complex and unwieldy data matrices. Principal Component Analysis (PCA) serves as a useful tool for identifying the most relevant traits by explaining the maximum possible variation in the original dataset using a minimal number of components, thereby simplifying the problem. In this context, the present study aims to evaluate and analyze genetic diversity through PCA and regression analysis to enhance yield in lettuce. (Ramesh et al., 2016).

Lettuce cultivation has a long-standing tradition in Slovenia. Alongside commercial production, it is commonly grown in home gardens across the country. Over centuries, numerous landraces have been developed, with one of the most well-known being ‘Ljubljanska ledenka.’ This variety is named after its place of origin, Ljubljana, the capital city of Slovenia. ‘Ljubljanska ledenka’ is classified as a crisphead lettuce, characterized by its heading growth habit, thick and crunchy leaves, and flabellate leaf venation. It is typically consumed raw. (de Vries and van Raamsdonk 1994). The original population of ‘Ljubljanska ledenka’ belongs to the Batavia type, characterized by yellowish-green, blistered leaves with dentate margins and a faint to pronounced red tint along the edges. Historical literature from a century ago identified it as a bolting-resistant variety (Avšič et al. 1966). However, under current climatic conditions, its bolting tendency classified as early to intermediate (Commission of the European Communities 1992; UKZUZ 2014).

In the 19th century, ‘Ljubljanska ledenka’ spread to Austria (Vienna and Graz), where it was marketed under the name ‘Laibacher Eis,’ the German equivalent of its original name. Over time, it appeared in various forms and names, including ‘Batavia glaciale de Laibach,’ ‘Glaciale de Laibach,’ ‘Hielo de Laibach,’ and ‘Laibacher Yskrop.’ These names, along with ‘Laibacher Eis,’ are listed as synonyms or closely related varieties to ‘Batavia Blonde à Bord Rouge’ (Rodenburg 1960). Within the ECC “Umbrella” varieties program for vegetables (Commission of the European Communities, 1992), ‘Ljubljanska ledenka’ is recognized as an umbrella variety. Derived varieties have since been included in the EU Common Catalogue of Varieties of Vegetable Species as ‘Blonde à Bord Rouge’ 2, 3, 4, and 5, along with their synonyms, such as ‘Laibacher Eis,’ ‘Grazer Krauthäuptel,’ and ‘Glaciale di Lubiana’ (European Commission, 2018).

MATERIAL AND METHODS

The present research was conducted During 2024 at Experimental Area of Plant Breeding and Genetics Department, Sindh Agriculture University, Tandojam. In order to Evaluation of exotic Lettuce (*Lactuca sativa* L.) Lines for the growth and yield performance under tandojam zone. The Experiment was followed in Randomized Complete Block Design (RCBD) with Four Replications. There were 12 blocks distribute in four replications. For present study three Genotypes was use to evaluation *viz*: Green leaf lettuce, Italic Lettuce and Red Green Dragon Lettuce. The following parameters were recorded *viz:* Chlorophyll Content (SPAD), Number of Leaves plant^{-1}, Plant Spreading (cm), Width of Leaves(cm), Length of Leaves (cm), Plant Height (cm) Root Depth (cm), Fresh Weight of Shoot (g) Fresh Weight of Root (g), Dry Weight of Root (g) and Dry Weight of Shoot (g). The collected data from various observations were statistically analyzed

using Statistics 8.1 computer software (Statistix, 2006). The LSD test was applied to compare treatment superiority, where necessary at (P<0.05).

Different parameters of calculating the germination growth and development are mentioned below.

chlorophyll content (SPAD)

With the Help of (SPAD-502) Digital chlorophyll content machine.

Number of leaves plant^{-1}

The number of leaves plant^{-1} were counted visually at the end of experiment from randomly 10 plants of each block.

Plant spreading (cm)

Plant spreading (cm) was measured with the help of Vernier caliper at the maturity of crop.

Width of leaves (cm)

Measuring tape was used to calculate the width of leaves from widest point to perpendicular to longitudinal axis.

Length of leaves (cm)

Measuring tape was used to calculate the length of leaves from tip to the petiole of the leaf.

Plant height (cm)

Measuring tape was used to calculate the plant height from bottom to the top of the plant.

Root Depth (cm)

Measuring tape was used to calculate the root depth from collar to the end of the root.

Fresh Weight of Shoot (g)

Fresh Weight of shoot was measured with the help of digital weight balance by randomly selected ten plants from each block. The shoot was washed in tap water and drain out excess water for two hours (Westlake 1965).

Fresh Weight of root (g)

Fresh Weight of root was measured with the help of digital weight balance by randomly selected ten plants from each block. The root was washed in tap water and drain out excess water for two hours (Westlake 1965).

Dry Weight of Shoot (g)

After recording data of dry weight of shoot were dried at room temperature for 5 to 7 days. The data of dry biomass of leaves was measured with the help of digital weight balance by randomly selected four plants from each treatment (Westlake 1965).

RESULTS AND DISCUSSION

Chlorophyll Content (SPAD)

The Chlorophyll Content (SPAD) primarily reflects the cultivar effect or reaction of the plant to management conditions. (Table-1) shows significant (P<0.05) results of an analysis of variance Chlorophyll Content (SPAD) of Lettuce under agro-ecological conditions of Tandojam. Data in (Table-1) depicts that maximum Chlorophyll Content (SPAD) (47.42 SPAD) of Lettuce was determined in G_3= Red Green Dragon Lettuce, followed by the G_1= Green Leaf Lettuce Chlorophyll Content (36.14 SPAD), respectively. While the minimum Chlorophyll content (30.54 SPAD) was noted in G_2= Italic Lettuce.

Table 1. Chlorophyll Content (SPAD), Number of Leaves plant^{-1}, Plant Spreading (cm) and Width of Leaves as effected by different Genotypes of Lettuce under Tandojam area

Genotypes	Chlorophyll Content (SPAD)	Number of leaves plant^{-1}	Plant Spreading (cm)	Width of Leaves (cm)
Green Leaf Lettuce	36.14 b	35.90 b	46.32 a	15.31 a
Italic Lettuce	30.54 c	37.20 a	32.25 b	8.13 b
Red Green Dragon Lettuce	47.42 a	15.50 c	31.01 c	4.49 c
F-value	4.77	10.1	11.59	13.58
P-value	0.0217	0.0000	0.0000	0.0000
CV	32.74	41.00	21.62	50.74
LSD	11.69	11.37	7.42	4.43

Number of leaves plant^{-1}

The Number of Leaves Plant^{-1} primarily reflects the cultivars effects or reaction of the plant management condition. (Table-1) Shows significant (P<0.05) results of an analysis of variance Number of leaves plant^{-1} of Lettuce under

Tandojam area. Data in (Table-1) depicts that maximum Number of leaves (37.20) of Lettuce was determined in G_2= Italic Lettuce, followed by the G_1= Green Leaf Lettuce Number of Leaves (35.90), respectively. While the minimum Number of leaves (15.50) was noted in G_3= Red Green Dragon Lettuce.

Plant Spreading (cm)

The Plant Spreading (cm) primarily reflects the cultivars effects or reaction of the plant management condition. (Table-1) Shows significant ($P<0.05$) results of an analysis of variance Plant Spreading (cm) of Lettuce under Tandojam area. Data in (Table-1) depicts that maximum Plant Spreading (cm) (46.32cm) of Lettuce was determined in G_1= Green Leaf Lettuce, followed by the G_2= Italic Lettuce Plant Spreading (cm) (32.25cm), respectively. While the minimum Plant Spreading (31.01cm) was noted in G_3= Red Green Dragon Lettuce.

Width of Leaves (cm)

The Width of Leaves (cm) primarily reflects the cultivars effects or reaction of the plant management condition. (Table-1) Shows significant ($P<0.05$) results of an analysis of variance Width of Leaves (cm) of Lettuce under Tandojam area. Data in (Table-1) depicts that maximum Width of Leaves (cm) (15.31cm) of Lettuce was determined in G_1= Green Leaf Lettuce, followed by the G_2= Italic Lettuce Plant Spreading (cm) (8.13cm), respectively. While the minimum Plant Spreading (4.49cm) was noted in G_3= Red Green Dragon Lettuce.

Table 2. Length of Leaves, Plant Height and Root Depth as effected by different Genotypes of Lettuce under Tandojam area

Genotypes	Length of Leaves (cm)	Plant Height (cm)	Root Depth (cm)
Green Leaf Lettuce	17.99 b	22.68 b	10.2 b
Italic Lettuce	11.51 c	12.46 c	9.87 c
Red Green Dragon Lettuce	24.55 a	25.32 a	12.03 a
F-value	93.51	40.23	2.35
P-value	0.0000	0.0000	0.1237
CV	11.83	16.8	22.42
LSD	2.00	3.18	2.25

Length of Leaves (cm)

The Length of Leaves (cm) primarily reflects the cultivars effects or reaction of the plant management condition. (Table-2) Shows significant ($P<0.05$) results of an analysis of variance Length of Leaves (cm) of Lettuce under Tandojam area. Data in (Table-2) depicts that maximum Length of Leaves (cm) (24.55 cm) of Lettuce was determined in G_3= Red Green Dragon Lettuce, followed by the G_1= Green Leaf Lettuce Length of Leaves (cm) (17.99 cm), respectively. While the minimum Length of Leaves (11.51 cm) was noted in G_2= Italic Lettuce.

Plant Height (cm)

The Plant Height (cm) primarily reflects the cultivars effects or reaction of the plant management condition. (Table-2) Shows significant ($P<0.05$) results of an analysis of variance Plant Height (cm) of Lettuce under Tandojam area. Data in (Table-2) depicts that maximum Plant Height (cm) (25.32cm) of Lettuce was determined in G_3= Red Green Dragon Lettuce, followed by the G_1= Green Leaf Lettuce Plant Height (cm) (22.68cm), respectively. While the minimum Plant Height (12.46 cm) was noted in G_2= Italic Lettuce.

Root Depth (cm)

The Root Depth (cm) primarily reflects the cultivars effects or reaction of the plant management condition. (Table-2) Shows non-significant ($P>0.05$) results of an analysis of variance Root Depth (cm) of Lettuce under Tandojam area. Data in (Table-2) depicts that maximum Root Depth (cm) (12.03 cm) of Lettuce was determined in G_3= Red Green Dragon Lettuce, followed by the G_1= Green Leaf Lettuce Root Depth (cm) (10.2cm), respectively. While the minimum Root Depth (9.87cm) was noted in G_2= Italic Lettuce.

Table 3. Fresh Weight of Shoot (g) and Fresh Weight of Root (g) as effected by different Genotypes of Lettuce under Tandojam area

Genotypes	Fresh Weight of Shoot (g)	Fresh Weight of Root (g)
Green Leaf Lettuce	59.63 a	2.47 a
Italic Lettuce	36.70 b	1.85 c

Red Green Dragon Lettuce	25.77 c	2.95 b
F-value	4.31	1.86
P-value	0.0295	0.1840
CV	64.65	52.23
LSD	24.72	1.2

Fresh Weight of Shoot (g)

The fresh weight of shoots (g) in the lettuce crop, as shown in Table-3, suggests that this characteristic is influenced more by the cultivar's effects rather than by plant management conditions, given the significant results ($P<0.05$) from the analysis of variance. The data reveal that the G_1= Green Leaf Lettuce achieved the greatest Fresh weight of shoots, measuring (59.63g). This was followed by the G_2= Italic Lettuce with a fresh weight of shoots of (36.70g). In contrast, the G_3= Red Green Dragon Lettuce exhibited the lowest fresh weight of shoots (25.77g).

Fresh Weight of Root (g)

The fresh weight of roots (g) in the lettuce crop, as shown in Table-3, suggests that this characteristic is influenced more by the cultivar's effects rather than by plant management conditions, given the non-significant results ($P>0.05$) from the analysis of variance. The data reveal that the G_3= Red Green Dragon Lettuce achieved the greatest Fresh weight of Roots, measuring (2.95 g). This was followed by the G_1= Green leaf lettuce with a fresh weight of Roots of (2.47 g). In contrast, the G_2= Italic Lettuce exhibited the lowest fresh weight of roots at (1.85g).

Table 4. Dry Weight of Root (g) and Dry Weight of Shoot (g) as effected by different Genotypes of Lettuce under Tandojam area

Genotypes	Dry Weight of Root (g)	Dry Weight of Shoot (g)
Green Leaf Lettuce	0.57 c	5.66 a
Italic Lettuce	0.68 b	3.72 b
Red Green Dragon Lettuce	0.81 a	3.02 c
F-value	2.63	3.59
P-value	0.09	0.04
CV	34.83	55.12
LSD	0.22	2.14

Dry Weight of Root (g)

The Dry weight of roots (g) in the lettuce crop, as shown in Table-4, suggests that this characteristic is influenced more by the cultivar's effects rather than by plant management conditions, given the non-significant results ($P>0.05$) from the analysis of variance. The data reveal that the G_3= Red Green Dragon Lettuce achieved the greatest dry weight of Roots, measuring (0.81g). This was followed by the G_2= Italic Lettuce with a Dry weight of Roots of (0.68g). In contrast, the G_1= Green leaf lettuce exhibited the lowest dry weight of roots at (0.57g).

Dry Weight of Shoot (g)

The dry weight of shoots (g) in the lettuce crop, as shown in Table-4, suggests that this characteristic is influenced more by the cultivar's effects rather than by plant management conditions, given the significant results ($P<0.05$) from the analysis of variance. The data reveal that the G_1= Green Leaf Lettuce achieved the greatest dry weight of shoots, measuring (5.66g). This was followed by the G_2= Italic Lettuce with a dry weight of shoots of (3.72g). In contrast, the G_3= Red Green Dragon Lettuce exhibited the lowest dry weight of shoots (3.02g).

Table 5. Person Correlations Coefficients (r)for total Growth and Yield parameters

	DWOR	DWOS	FWOR	FWOS	LOL	NOLP	PH	PS	RD	SPAD
DWOS	0.1648									
FWOR	0.4914	0.4531								
FWOS	0.1968	0.7779	0.6123							
LOL	0.1495	-0.0402	0.3307	-0.1209						
NOLP	-0.2940	0.0627	-0.1668	0.0647	-0.5131					
PH	0.0115	-0.0165	0.2781	-0.0525	0.8243	-0.2092				

PS	-0.1942	0.1616	0.0543	0.1986	0.0408	0.4249	0.2834			
RD	0.2303	-0.0284	0.3972	-0.0410	0.4390	-0.0510	0.4777	0.0857		
SPAD	0.3495	0.0262	0.6322	0.2018	0.4677	-0.3210	0.3562	-0.0674	0.3660	
WOL	-0.1514	0.5560	0.1183	0.6475	-0.1549	0.2105	-0.1851	0.3814	0.3649	-0.0866

DWOS= Dry Weight of Shoot (g), DWOR= Dry Weight of Root (g), FWOS= Fresh Weight of Shoot (g), FWOR= Fresh Weight of Root (g), LOL= Length of Leaves (cm), NOLP= Number of leaf plant, PH= Plant Height (cm), PS= Plant Spreading (cm), RD= Root Depth (cm), SPAD= Chlorophyll Content, WOL= Width of Leaves (cm)

Pearson correlation coefficients

The correlations in Table 5 provide comprehensive insights into the interplay between growth and yield parameters, shedding light on potential synergies and trade-offs in plant development. Strong positive correlations, such as between plant height (PH) and leaf length (LOL, r=0.8243r = 0.8243r=0.8243) or fresh shoot weight (FWOS) and leaf width (WOL, r=0.6475r = 0.6475r=0.6475), suggest that taller plants with longer leaves and broader leaves with heavier shoots tend to perform well in terms of biomass accumulation. Similarly, chlorophyll content (SPAD), a critical indicator of photosynthetic efficiency, shows a moderate positive correlation with fresh root weight (FWOR, r=0.6322r = 0.6322r=0.6322), emphasizing the role of chlorophyll in supporting root growth. Moderate correlations between root depth (RD) and SPAD (r=0.3660r = 0.3660r=0.3660) further highlight the importance of deeper roots in nutrient uptake and photosynthetic capacity, indirectly supporting overall plant vigor.

Negative correlations reveal key trade-offs, such as between leaf length (LOL) and the number of leaves per plant (NOLP, r=−0.5131r = -0.5131r=−0.5131), indicating that longer leaves may limit the production of additional leaves, a consideration for optimizing both biomass and aesthetic traits in plants. Similarly, weak negative correlations, like that between dry shoot weight (DWOS) and leaf width (WOL, r=−0.1514r = -0.1514r=−0.1514), while less impactful, suggest subtle interactions that may influence overall plant morphology.

The data also underscore the complex balance between growth attributes, as seen in the positive yet weak correlation between plant spreading (PS) and leaf width (WOL, r=0.3814r = 0.3814r=0.3814), suggesting that wider leaves slightly contribute to increased canopy coverage. This interplay of traits highlights the importance of multi-trait selection in breeding programs to enhance productivity, resilience, and efficiency. By leveraging these correlations, breeders and agronomists can design targeted strategies to maximize desirable traits, minimize trade-offs, and improve overall crop performance in diverse environments.

CONCLUSIONS

The study conducted during Winter 2023-24 at the Experimental Area of the Plant Breeding and Genetics Department, Sindh Agriculture University, Tandojam, revealed significant variation in growth, yield, and physiological traits among three lettuce genotypes: Green Leaf Lettuce, Italic Lettuce, and Red Green Dragon Lettuce. Red Green Dragon Lettuce exhibited the highest chlorophyll content (47.42 SPAD), longest leaves (24.55 cm), tallest plants (25.32 cm), and deepest roots (12.03 cm), indicating superior physiological development. Conversely, Italic Lettuce recorded the lowest values for these traits, including minimum chlorophyll content (30.54 SPAD) and leaf length (11.51 cm), suggesting relatively weaker performance. Green Leaf Lettuce demonstrated outstanding yield traits, including the widest leaves (15.31 cm) and maximum leaf yield, making it the most suitable genotype for cultivation under the agro-ecological conditions of Tandojam. Based on these findings, Green Leaf Lettuce is recommended for growers aiming for higher leaf yield in similar climatic conditions.

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AUTHOR CONTRIBUTIONS

All authors contributed equally to this research.

COMPETING OF INTEREST

The authors have declared no conflict of interest.

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