Investigation and Research on the Germplasm Resources of Basu Zui Pear in Changdu City

Liu Shuang[1, #], Han Yanying[1, #], Zhou Yuliu[1], Jing Aohang[1], Zha Xisangbu[2], Yang Guoxiong[2], Ye Yanhui[1, *]

[1]Resources & Environment College, Xizang Agriculture & Animal Husbandry University, Linzhi 860000, China

[2]ChinaChangdu City Basu County Agriculture, Rural Affairs and Science and Technology Water Resources Bureau, Linzhi 854600, China

Abstract: To comprehensively understand the distribution, quantity, age, yield, and fruit quality of the inebriating pear in Basu County, and to systematically carry out the comprehensive collection and precise identification of the inebriating pear germplasm resources in Basu County, so as to provide accurate data basis for the subsequent protection, utilization and management of the germplasm resources. The fruit tree resources of inebriating pear in Basu County, Changdu City were investigated through on-site investigation, interview investigation and route investigation. Due to the influence of the "high in the north and low in the south" terrain of the Three Rivers Basin and the plateau temperate semi-arid monsoon climate (annual average temperature 10.4 ℃, precipitation 233.3mm, frost-free period 161.7 days), the inebriating pear shows obvious vertical distribution adaptability, and forms a concentrated planting area in the river valley at an altitude of 2800-3200m. The principal component analysis (PCA) of fruit quality revealed that single fruit weight, transverse diameter, and soluble solids content were the dominant contributors to the first principal component, explaining nearly half of the total variance. Notably, Ziga Village exhibited the highest comprehensive fruit quality score. In contrast, Lagen Village exhibited higher fruit hardness and stone cell content, contributing to its high score in the second principal component. the lowest fruit shape index was found in Lieri Village, indicating a relatively flattened fruit shape, while other villages had values closer to or exceeding 0.8. Through the investigation and research on the distribution and growth of inebriating pear in Basu County this time, it provides a reference basis for the rational utilization, resource protection and artificial cultivation of inebriating pear resources in Basu County.

Keywords: Basu; Zui Pear; Resources; Investigation

DOI: 10.57237/j.jaf.2026.01.001

Funding: Project of Central Government Guiding Local Science and Technology Development Funds: Investigation, Protection, and Excavation of Superior Strains of Basu Zui Pear Germplasm Resources (CDKJ-ZYYDDF2024001); Key Research and Development Plan of the Science and Technology Program of the Xizang Autonomous Region: Research and Demonstration of Fruit-Grass Intercropping Technology in Apple Orchards in Xizang (XZ202401ZY0032); Science and Technology Plan Project of Linzhi City: Research and Demonstration of Fruit-Grass Intercropping and Scientific Formula Fertilization Technology in Apple Orchards in Linzhi City (2023-XYQ-006); Construction and Comprehensive Service Capacity Enhancement of Science and Technology "Xiaoyuan" for Plateau-Characteristic Agriculture and Animal Husbandry (XY2024-03, XK2024-04, XK2024-01, YJSXK2025-22, YJSXY2025-05); Graduate Education Innovation Program Projects of Xizang Agriculture and Animal Husbandry University (YJS2024-28, YJS2024-26, YJS2024-31); Science and Technology Major Project of the Xizang Autonomous Region of China (XZ202201ZD0005G02); Major Science and Technology Project of the Science and Technology Program of the Xizang Autonomous Region of China (XZ202101ZD003N); Forestry Doctoral Program (Phase I) of Xizang Agriculture and Animal Husbandry University (533325001), The 7th Batch of Flexible Talent Introduction Project of Xizang Agriculture and Animal Husbandry University (53013001804).

*Corresponding author: Ye Yanhui, 260383872@qq.com

Liu Shuang and Han Yanying are co-first authors.

Received: 18 September 2025; Accepted: 21 May 2026; Published Online: 30 May 2026 http://www.agrforestry.com

1 Introduction

China, as a continental country with diverse climates, boasts the world's richest germplasm resources of the pear genus. The country has a long history of pear cultivation, dating back at least 3,000 years. Due to site-specific adaptations, pears are the third most widely cultivated and produced fruit in China, following apples and citrus fruits [1]. National surveys conducted in the 1950s and 1980s identified over 3,000 local pear varieties (landraces) distributed across China [2]. The pear industry in Xizang has developed relatively slowly, contributing a small share to the country's overall production area and yield [3]. Changdu City, the first administrative center to be liberated in Xizang, was also the earliest area in the region to introduce fruit tree cultivation and now holds abundant fruit tree resources. Basu County is one of the primary distribution areas for Xizang Zui pears, a unique highland fruit resource adapted to high altitudes, low temperatures, and strong sunlight. It features a distinctive flavor and significant economic potential. Pear belongs to the genus (*Pyrus L.*) of the subfamily (*Maloideae*) of the family (*Rosaceae*), and is one of the main economic tree species in the region [4]. The fruit has a crisp texture, juicy flesh, and a sweet taste, making it suitable for both fresh consumption and processing into various pear products [5]. As a local specialty fruit resource, Zui pears are distributed across 14 villages in Basu County, including Jiba, Xiba, Wada, and Walai. The fruit is oval-shaped, with yellow skin covered in numerous lenticels. Its yellowish-white flesh is crisp but slightly coarse, juicy and sweet, with a slightly large core and some residue after eating. The fruit weighs between 200 and 700 grams. The Zui pear is a multipurpose tree species with medicinal and ornamental value. Its roots, leaves, and fruits can all be used medicinally. The roots and leaves are known for their lung-moistening, cough-relieving, heat-clearing, and detoxifying properties, while the fruits provide benefits such as generating fluids, moisturizing dryness, clearing heat, and resolving phlegm.

In the Xizang Autonomous Region, complex terrain and diverse ecological and climatic conditions have nurtured rich wild pear germplasm resources. However, most of these resources remain underutilized, and systematic scientific research on Xizang pear germplasm resources is still limited [6]. Through long-term agricultural practices, local communities have cultivated numerous excellent local pear varieties through continuous innovation and domestication. These varieties possess rich genetic diversity, providing a valuable foundation for future cultivar breeding and genetic improvement. Nevertheless, local varieties have faced severe genetic erosion in recent years, underscoring the urgent need for systematic collection, preservation, and research efforts [7]. As a distinctive fruit of Changdu and an important economic crop, the Zui pear has gained broader recognition. However, there remains a lack of systematic investigation and research on this fruit. Therefore, this study focuses on the Zui pear of Basu County, Changdu Prefecture, by investigating its distribution, yield, and fruit quality, and by systematically collecting and analyzing relevant data. The aim is to provide essential data to support the cultivation, conservation, and development of the Zui pear in Basu County, Changdu Prefecture, Xizang Autonomous Region.

2 Materials and Methods

2.1 Overview of the Test Site

The experimental site in Basu County, Changdu Prefecture, is located between N29°40′–31°01′ and E96°23′–97°28′, with a total area of 12,564.28 km². The region is situated in the high mountain and canyon area of the Three Rivers Basin, characterized by rugged terrain. The topography generally slopes from higher elevations in the north to lower elevations in the south. The altitude of the survey points ranges between 2728.9 m and 3352.4 m. Due to significant topographical variations, climatic factors such as temperature and precipitation vary noticeably with changes in altitude and geographic location. This results in three distinct vertical climatic zones: the warm temperate valley zone, the plateau temperate zone, and the plateau cold temperate zone. The predominant climate is the semi-arid monsoon climate of the plateau temperate zone. The region experiences an average annual precipitation of 233.3 mm and an average annual temperature of 10.4 ℃. The climate is characterized by significant vertical climatic differences, ample sunlight, and distinct dry and rainy seasons. The frost-free period lasts for 161.7 days per year. Summers are mild and humid, while winters are cold and dry. Although the annual temperature variation is relatively small, the diurnal temperature range is significant. The region enjoys

abundant solar resources, with annual sunshine hours ranging from 2100 to 2700 hours. The region experiences low annual precipitation, averaging 233.3 mm, with most rainfall concentrated between May and September, highlighting a distinct "dry and wet season" pattern. The maximum annual evaporation rate in Basu County reaches 2617.2 mm, which is more than 11 times the annual precipitation (233.3 mm), indicating relatively low humidity levels [8].

2.2 Investigation Method

2.2.1 Sample Line Survey

From September 14 to 21, 2024, a survey was conducted using the transect method to investigate villages in Basu County, Changdu Prefecture, Xizang Autonomous Region, where Zui Pear cultivation exists. The survey covered 14 villages. Data on the distribution points of Zui Pear, including latitude, longitude, altitude, and yield, were recorded during the transect survey.

2.2.2 Conducting Field Investigations

Tree height was measured using a Blume-Leiss altimeter; diameter at breast height (DBH) was determined using a measuring tape at a height of 1.3 meters above the ground [9]. Crown width was measured in both east-west and north-south directions, with the vertical projection of the crown as the reference point to determine its size. Tree age was primarily estimated by measuring DBH, consulting relevant literature calculation methods, and conducting field interviews. For ancient trees where the age could not be determined or required precise identification, increment core sampling was performed using an increment borer.

2.3 Data Analysis

After completing the field survey and fruit measurements, all data were initially entered and organized using Excel 2021 software. Subsequently, SPSS 24.0 software was used to perform descriptive statistical analysis, analysis of variance (ANOVA), and multiple comparison tests to evaluate the significant differences in the growth status and fruit traits of Zui pear resources across different villages.

For fruit trait indicators, principal component analysis (PCA) was further employed to reduce dimensionality and integrate multiple indicators. Principal components with eigenvalues greater than 1 were extracted, and the component loading matrix was calculated to identify the key contributing indicators, determine their comprehensive scores, and rank them. The variance contribution rate of each principal component in PCA was used to determine its weight in the comprehensive evaluation model. Based on the principal component scores and weights, a comprehensive evaluation model of Zui pear fruit quality was constructed.

3 Results and Analysis

3.1 Resource Growth Status of Basu Zui Pear

To study the distribution and characteristics of Zui Pears (Pyrus sp.) in Basu County, Changdu City, a field survey and collection were conducted from September 14 to September 21, 2024. The investigation covered 14 villages and involved over 3,000 trees. Measurements of crown width (both horizontal and vertical), yield, diameter at breast height (DBH), and tree height were recorded.

The survey results showed that the maximum DBH among the sampled trees was 113 cm, while the minimum was 6 cm. Most trees had a DBH ranging between 20 cm and 40 cm. The measured tree height, defined as the vertical distance from the base of the above-ground part (where the roots connect to the stem) to the tree top (excluding inflorescences or immature fruits), reached a maximum of 17.80 m. However, in Sample Plot ② of Xiba Village, where seedlings were artificially planted and tree age was relatively young, the standard tree height, crown width (both horizontal and vertical), and overall size were the smallest. These younger trees exhibited smooth trunks, gray-white bark, spines, small tree forms, smaller crowns, and either no fruit or very small fruit. (Refer to 1 for details).

Table 1 Growth status of Zui pear in different villages

sample plot (village)	DBH (cm)	Height (m)	Horizontal crown spread (m)	Vertical crown spread (m)	Harvest (a)
Jiba	58.3	11.7	11.0	9.0	1300
Xiba (1)	32.0	9.1	7.9	6.7	1353
Xiba (2)	8.0	6.2	2.8	2.7	——
Wada	34.3	8.0	7.0	7.5	857
Walai	38.2	12.3	9.9	9.6	906

sample plot (village)	DBH (cm)	Height (m)	Horizontal crown spread (m)	Vertical crown spread (m)	Harvest (a)
Niba	25.8	9.1	9.0	9.4	872
Genyao	38.8	12.6	7.6	8.8	896
Gama	32.0	10.6	5.8	9.2	1010
Zhuba	34.1	8.7	8.0	8.9	704
Xiaxin	49.7	8.9	9.9	10.3	2139
Lieri	36.0	10.0	6.7	10.1	373
Genyao	19.0	5.7	6.2	6.2	1394
Jiayuziran	31.5	9.5	9.5	5.7	704
Raoba	95.5	11.1	11.9	10.8	767
Ziga	88.7	12.9	12.9	13.1	510

3.2 Map of Pear Chest Diameter and Tree Height Distribution

The results of this experiment show that the diameter at breast height (DBH) of the Zui Pears in Basu County mainly ranges between 20 and 60 cm, with a decreasing trend at both ends. The tree height is primarily concentrated between 6 m and 12 m, with the majority falling in the 9-12 m range, as shown in Figure 1. During the survey, a Zui Pear tree with a DBH of 106 cm located in Jiayuziran Village was sampled for tree core and age determination. The tree was found to be 113 years old. The survey revealed that the majority of trees have a DBH between 20 and 60 cm, leading to the estimation that the age of most Zui Pear trees in Basu County is likely between 20 and 60 years. This indicates that the majority of these trees are transitioning from their productive phase to the senescence phase of their life cycle. The survey also found that Zui Pear trees in the Basu region were mostly planted in earlier years. If public awareness of the need to protect Zui Pear resources is not raised soon, their population is expected to decline rapidly.

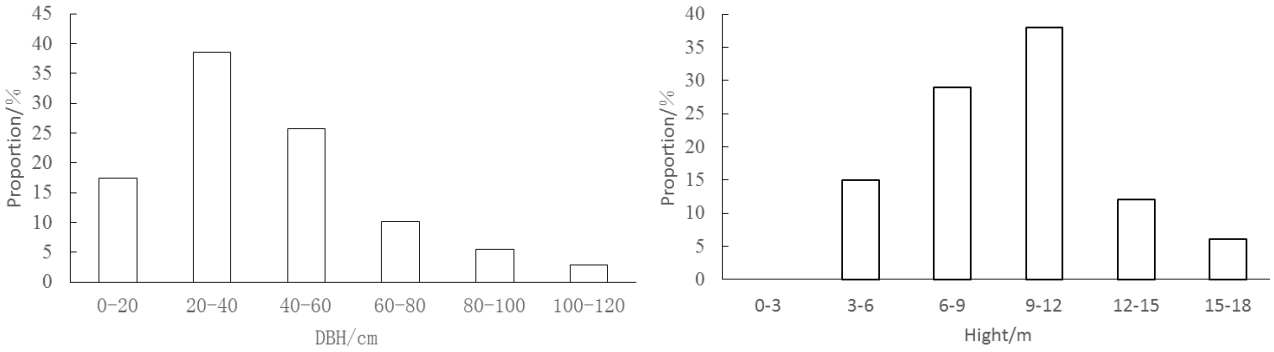

Figure 1 Distribution map of chest diameter and tree height of eight host pear resources

3.3 Comparison of Pear Growth in Different Locations

Due to the varying growth conditions of trees at different sampling sites in Basu County, some sites contain both century-old trees and one-year-old saplings. Therefore, in consideration of the actual circumstances, this survey will exclude trees with significant differences from others to minimize errors and ensure the accuracy of the experimental data. Through field investigation of the Zui Pears in Basu County, the results show that at the sampling sites in Raoba Village, Ziga Village, and Jiba Village, the Zui Pear resources generally have thicker trunks. In contrast, at sites such as Lagen Village, Niba Village, and Xiba Village, the trees tend to have thinner trunks. At Ziga Village, Genyao Village, and Wala Village, the Zui Pear trees are relatively taller, while at Lagen Village, Wada Village, and Zhuba Village, the trees are relatively shorter. At Raoba Village, Ziga Village, and Jiba Village, the horizontal canopy width of the Zui Pear resources is relatively larger, while at Lagen Village, Lieri Village, and Gama Village, the horizontal canopy width is relatively smaller. Lastly, at Ziga Village, Raoba Village, and Xiaxin Village, the vertical canopy width is relatively larger, while at Jiayuziran Village, Lagen Village, and Xiba Village, the vertical canopy width is relatively smaller.

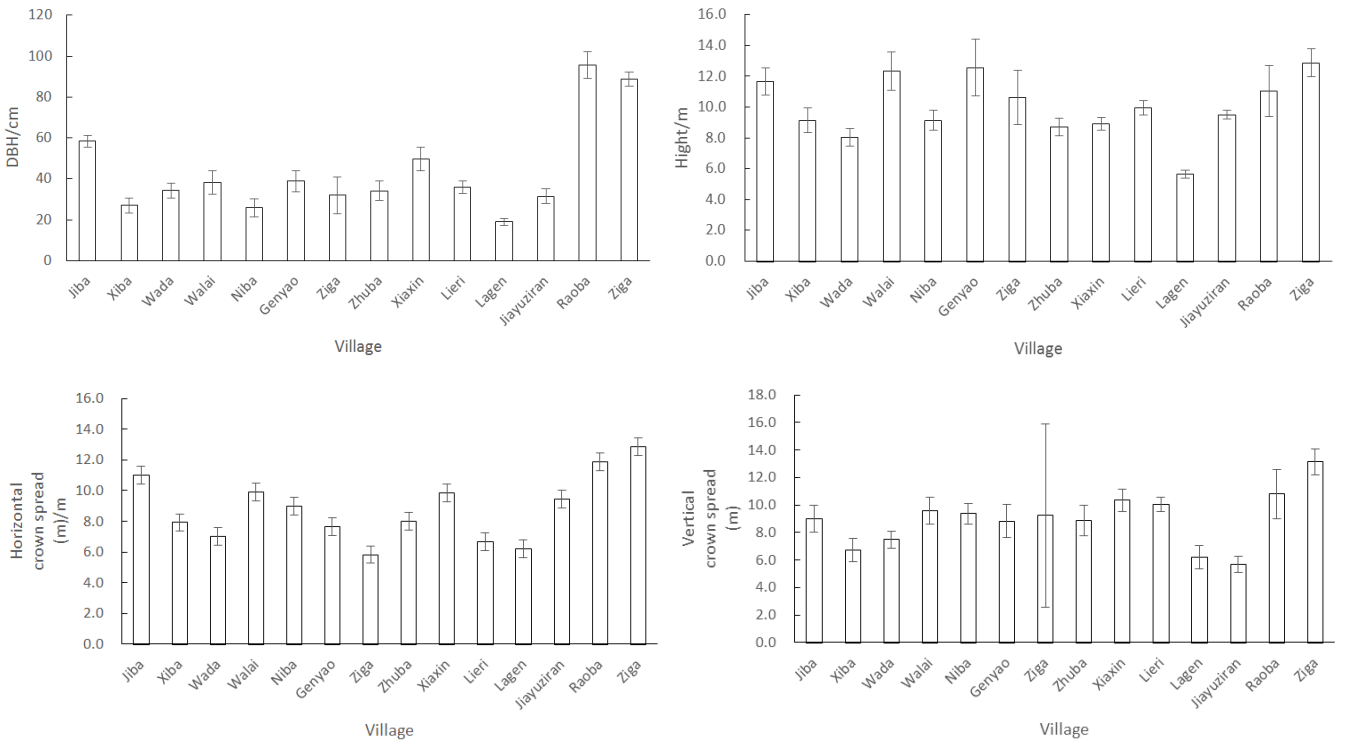

Figure 2 Growth of pear resources in different sites

3.4 Distribution of Zui Pear Resources in Basu County

Due to the unique characteristics of the plateau, the distribution of Zui Pears across the villages shows significant elevation differences. The lowest elevation is 2728.9m in Genyao Village, while the highest is 3352.4m in Xiaxin Village, with a maximum elevation difference of 623.5m. Currently, the Zui Pears in Basu County are mainly small, newly planted artificial forests and sporadically planted trees, with the main production areas being Ziga Village, Jiayuziran Village, and Gama Village. In terms of distribution types, the Zui Pears in the 14 sample villages mainly show two types: cluster distribution and random distribution. Based on the analysis in Table 2, the Zui Pears are predominantly distributed in dense clusters along the river valley regions at lower elevations.

Table 2 Overview of the distribution sites of Zui pear in Baxiu County

Village	longitude	latitude	Altitude /m	Total number of trees/a	Spatial pattern
Xiba (1)	96.965949	30.0677	3169	185	Reunion distribution
Xiba (2)	96.96849	30.06273	3161	-	Reunion distribution
Wada	97.123470	30.022955	2928	417	Random distribution
Walai	97.05636	30.01304	3092	97	Random distribution
Zhuba	96.87501	30.0557	3321	81	Random distribution
Xiaxin	96.866.037	30.05456	3352	36	Reunion distribution
Ziga	97.173759	30.005174	3034	48	Random distribution
Lieri	97.085913	30.02593	2983	749	Reunion distribution
Genyao	97.01423	30.0326	2983	170	Random distribution
Jiayuziran	97.01743	30.01587	3097	78	Random distribution
Raoba	97.03109	30.02008	3238	206	Random distribution
Niba	97.32183	29.87447	3087	21	Random distribution
Genyao	97.27322	30.07071	2729	415	Random distribution
Ziga	97.30293	30.09568	3291	604	Reunion distribution
Jiba	96.69176	30.454319	3094	25	Random distribution

3.5 Determination of Fruit Quality of Zui Pear in Basu County

In the sample sites of Basu County, after excluding edge trees, three pear trees with similar growth vigor were randomly selected. Once the fruits matured, three disease-free, undamaged, and fully ripe fruits from the inner and outer sections of each tree's eastern side were collected. The collected fruits were placed in self-sealing bags and taken back to the laboratory for measurement of various indices. According to the "Standards for Description and Data of Pear Germplasm Resources," the external shape of the fruits was determined. The individual fruit weight was measured using a balance with a precision of 0.01 g, and the fruit's horizontal and vertical diameters were measured using a caliper with a precision of 0.01 mm. Each index was measured three times, and the fruit shape index was calculated using the ratio of the fruit's vertical diameter to its horizontal diameter.

The internal quality indicators of the fruit included hardness, core horizontal diameter, soluble solids content, stone cell content, titratable acid content, vitamin C content, and acid-to-solid ratio. Fruit hardness was measured using a digital fruit hardness meter (GY-4, Aidebao, 8 mm). After cutting the fruit horizontally, the core horizontal diameter was measured with a caliper with a precision of 0.01 mm, and the core ratio was calculated using the ratio of core horizontal diameter to fruit horizontal diameter. The soluble solids content was measured using a handheld high-precision digital refractometer; titratable acid content was measured using the NaOH titration method, and the acid-to-solid ratio was calculated using the ratio of soluble solids content to titratable acid content. The vitamin C content was determined by the 2,6-dichlorophenolindophenol titration method, and the stone cell content was measured using the freezing method. Each index was repeated three times [10] (see Table 3).

Table 3 Methods for determining fruit quality

Test indicators	unit	assay method
Single fruit weight	g	Weigh on a balance
Length and diameter of fruit	mm	The vernier caliper was used to measure the transverse and longitudinal diameters of each fruit three times
Fruit shape index	-	Fruit length / fruit width
The fruit heart is horizontal in diameter	mm	Cross the equatorial part of the fruit and measure with a vernier caliper. Measure each fruit three times
The fruit heart ratio	-	Fruit heart diameter / fruit cross diameter
Fruit hardness	kg/cm^2	The hardness was measured by using the TYPE-GY-3 hardness meter, and each fruit was measured on three sides
Soluble solids content	%	Each fruit was measured on three sides by digital sugar meter
Titrate the acid content	%	It was determined by neutralization titration with sodium hydroxide
Solid acid ratio	-	Soluble solids content/detectable acid content
Vitamin C content	mg/100g	Dichlorophenol was used for determination
Stone cell content	g/100g	Determination by freezing method

Table 4 Summary of fruit external quality characteristics data

Number	Village	Appearance features	Single fruit weight (g)	transverse diameter (mm)	Longitudinal (mm)	Fruit shape index
1	Jiba	The pear is flat and round, with a green and orange-red background. Some of the colored pieces are red, without fruit rust, with medium fruit spots, no ridges or grooves, persistent sepals, aggregated sepals, shallow sepals, smooth sepals, medium fruit surface, no fragrance, erect fruit stalk posture, and medium stem depression	169.98	69.09	62.17	0.900
2	Raoba		242.77	79.88	62.70	0.785
3	Ziga		603.14	103.33	86.77	0.840
4	Lieri		273.06	83.35	59.45	0.713
5	Niba		161.90	68.12	56.49	0.829
6	Genyao		195.97	73.01	60.53	0.829
7	Walai		138.71	67.17	54.68	0.814
8	Wada		138.29	65.13	55.00	0.844

The smallest fruit shape index in Lie Village is 0.713, while the fruit shape indices of the other 10 villages range from 0.785 to 0.923. The fruit shape index is an indicator used to assess the shape of the fruit, reflecting the ratio of the fruit's vertical to horizontal diameters. A lower fruit shape index indicates that the fruit is more flattened, while a higher index suggests that the fruit is closer to a round or oval shape. This diversity may be related to factors such as

soil conditions, climate, and cultivation techniques in different villages. Ziga Village has the largest fruit size, which may be attributed to its location in a river valley, long sunlight exposure, high temperatures, abundant water resources, and its unique management practices. The fruit shape in Jiba Village is relatively good, while Lagen Village has the smallest core ratio, suggesting that the fruit flesh in this village has a larger proportion, resulting in a higher edible rate. The core ratio is a measure of the proportion of the fruit's core to its overall size. A lower core ratio means more flesh and less core, which is an important quality trait for consumers as it directly impacts both the edible and economic value of the fruit.

The smallest core ratio was found in Lagen Village, while the largest was in Lie Village. The fruit hardness is one of the important indicators of fruit maturity. Among the villages, Lagen Village had the highest fruit hardness at 11.41 kg cm^{-2}, while the lowest was in Wada Village at 4.86 kg cm^{-2}. In the 8 sampled sites, the soluble solid content was relatively high, with the lowest content in Niba Village at 10.91%, and the highest in Lie Village at 16.60%. The highest fruit moisture content was found in Wala Village at 86.4%, and the lowest in Lie Village at 80.7%. The highest stone cell content was in Lagen Village, with 1.55g/100g, while the lowest was in Wala Village at 0.68g/100g. Vitamin C (VC) is an important indicator of the nutritional value of fruits, and Ziga Village had the highest VC content. The total acid content and soluble sugar content directly affect the taste of the fruit, and fruits with higher sugar content are often more favored by consumers. There was little variation in the soluble sugar content of fruits among the 8 sampled sites (refer to Table 5).

Table 5 Summary of internal quality characteristics of fruits

Number	Village	The fruit heart ratio	Solidity (kg cm^{-2})	Soluble solids /%	Water content /%	Lithocyte (g/100g)	VC content (mg/100ml)	Total acid content (g/100ml)	Soluble sugar content /%
1	Jiba	0.413	10.78	13.64	83	1.05	3.07	0.49	9.51
2	Raoba	0.412	8.92	14.03	82.9	1.11	2.47	0.56	9.1
3	Ziga	0.421	7.97	15.87	82.5	0.94	3.5	0.50	9.36
4	Lieri	0.547	11.25	16.6	80.7	1.32	3.17	0.50	9.65
5	Niba	0.502	11.37	10.91	87.2	1.33	2.94	0.44	8.36
6	Lagen	0.352	11.41	12.58	84.6	1.55	2.89	0.41	10.11
7	Walai	0.354	7.91	11.33	86.4	0.69	2.85	0.45	9.43
8	Wada	0.392	4.86	13.9	83.6	0.68	2.48	0.59	10.02

3.6 Comprehensive Evaluation of Zui Pear Fruit Quality

3.6.1 Principal Component Analysis

The principal component analysis (PCA) results for fruit quality indicators of Zui pears from eight tested villages are presented in Table 6. As shown in Table 5, the cumulative variance contribution rate of the three principal components reached 86.209%, with eigenvalues all exceeding 1, indicating that these three components effectively summarize the majority of information from the 12 original fruit quality traits. The first principal component, accounting for 46.392% of the variance, was predominantly influenced by nine indicators: single fruit weight, transverse diameter, longitudinal diameter, core transverse diameter, core ratio, soluble solids content, total acid content, solid-acid ratio, and vitamin C (VC) content. The second principal component contributed 23.898% of the variance and was primarily associated with two indicators: fruit firmness and stone cell content. The third principal component explained 15.919% of the variance and was largely determined by the fruit shape index.

Table 6 Principal component loadings matrix of quality indexes of 8 test villages

Fruit quality indicators	Loading of each principal component		
	Principal 1	Principal 2	Principal 3
Single fruit mass	0.866	-0.374	0.264
Fruit transverse diameter	0.917	-0.294	0.127
Fruit longitudinal diameter	0.778	-0.396	0.439

Fruit quality indicators	Loading of each principal component		
	Principal 1	Principal 2	Principal 3
Fruit shape index	-0.372	-0.223	0.731
Core transverse diameter	0.914	0.005	-0.331
Fruit-to-heart ratio	0.509	0.341	-0.615
Fruit frmness	0.3	0.908	0.07
Soluble solid content	0.761	-0.365	-0.347
Soluble solid content	-0.052	-0.773	-0.549
Solid-acid ratio	0.851	0.252	0.116
Stone cell content	0.327	0.823	-0.028
Vitamin C content	0.797	0.155	0.41
Characteristic root	5.567	2.868	1.91
Variance contribution rate /%	46.392	23.898	15.919
Cumulative variance contribution rate /%	46.392	70.289	86.209

3.6.2 Establishment of the Comprehensive Evaluation System

Table 7 Factor Score Coefficient Matrix

Component score coefficient matrix			
	F1	F2	F3
Jiba (X1)	-0.26816	0.17933	0.73598
Raoba (X2)	-0.19061	-0.49968	-0.85496
Ziga (X3)	1.74478	-1.18873	1.11463
Lieri (X4)	1.26562	0.74525	-1.65102
Niba (X5)	-0.34106	1.16968	-0.09581
Lgen (X6)	-0.16249	1.16013	0.98761
Walai (X7)	-0.97096	-0.14678	0.49277
Wada (X8)	-1.07713	-1.41919	-0.72919

The membership function calculation referenced the method described by Liu Yaxi [11]. The membership function is defined as:

$$R(X_i) = (X_i - X_{min})/(X_{max} - X_{min})$$

where Xi represents the factor score of indicator i, and Xmin and Xmax denote the minimum and maximum values of the cumulative product of factor scores and corresponding weights for indicator i across all treatments. A comprehensive mathematical model for the integrated score (F) of each principal component was established using the variance contribution rates of the principal components as weights. The model is expressed as: $F_f = (49.392f_1+23.898f_2+ 15.919f_3)/86.209$, where F_f represents the comprehensive fruit quality score, and f_1, f_2, and f_3 correspond to the scores of the first, second, and third principal components of the fruit quality indicators, respectively. Using this model, the comprehensive scores of each pear variety were calculated and ranked (Table 8).

Table 8 The comprehensive evaluation results of the fruit quality of 8 participating villages were evaluated

Village	Overall score	Reorder
Jiba	2.302	5
Raoba	1.901	7
Ziga	2.662	1
Lieri	2.513	3
Niba	2.376	4
Lagen	2.609	2
Walai	1.968	6
Wada	1.431	8

3.7 The Distribution Area and Preservation Status of Basu Zui Pears Resources

To investigate the distribution of Zui pears in Basu County, Changdu City, and conduct research, an investigation was carried out in Basu County from September 14 to September 21, 2024. The survey results showed that Zui pears are distributed in all 14 villages under the jurisdiction of Basu County, with the main distribution type being random. Overall, Zui pears are densely distributed along the river valley areas at lower elevations, and the preservation status is relatively intact. Currently, Zui pears in Basu County are primarily cultivated in small, newly planted artificial forests and scattered plantings, with the main production areas being Ziga Village, Jiayuziran Village, Gama Village, and other villages. The survey results indicate that in the Changdu Basu region, Zui pears are mainly distributed in 14 villages, with Lie Village having the highest distribution and Niba Village having the lowest. There is significant distribution variation between villages, which can

be preliminarily attributed to local climate and spatial factors.

4 Discussion

4.1 Growth Characteristics and Environmental Adaptation Mechanisms

The results of this study showed that the diameter at breast height (DBH) of Zui Pears (Pyrus sp.) in Basu County predominantly ranged from 20 to 60 cm, with only a few trees exceeding 60 cm. This distribution suggests that most Zui Pear trees are in their mid to late reproductive stage, which is consistent with the observation that many of these trees were planted decades ago during early afforestation efforts. Trees with larger DBH values were mainly found in Raoba, Ziga, and Jiba Villages, areas located in relatively lower altitude river valleys. These regions are characterized by deeper soils, higher soil moisture, and warmer microclimates compared to higher elevation sites (e.g., Lagen and Xiaxin Villages), which likely promotes more vigorous vegetative growth. Previous studies have indicated that pear growth is highly sensitive to water availability and soil depth, which can significantly influence trunk diameter and tree height development [12, 13]. Furthermore, tree height was primarily concentrated between 9 and 12 meters, with taller trees observed in Ziga, Genyao, and Walai Villages. These locations are closer to river valleys with higher solar radiation, which enhances photosynthetic rates, promoting vertical growth. Conversely, sites like Lagen, Wada, and Zhuba Villages, with higher elevations and more exposure to cold winds, exhibited lower tree heights. The vertical gradient in climate (e.g., temperature, precipitation) in this region creates a pronounced zonation in Zui Pear growth, consistent with the concept of vertical climate belts widely documented in plateau ecosystems [14, 15].

4.2 Fruit Quality Variations and Physiological Mechanisms

The principal component analysis (PCA) of fruit quality revealed that single fruit weight, transverse diameter, and soluble solids content were the dominant contributors to the first principal component, explaining nearly half of the total variance. Notably, Ziga Village exhibited the highest comprehensive fruit quality score, primarily due to its superior single fruit weight and higher soluble solids content. This can be mechanistically explained by the site's favorable hydrothermal conditions—higher precipitation, longer sunshine hours, and more moderate temperatures—which support robust carbohydrate synthesis and accumulation of sugars during fruit development [16]. Such conditions have been shown to enhance sink strength in fruit trees, leading to increased fruit size and sugar content [17].

In contrast, Lagen Village exhibited higher fruit hardness and stone cell content, contributing to its high score in the second principal component. The increased stone cell formation is often a defense response to environmental stress (e.g., low temperature or water stress) and can affect fruit texture [18]. This suggests that the local microclimate, with larger diurnal temperature differences and potentially higher wind exposure, may have induced stress responses in Zui Pear trees, leading to thicker fruit walls and higher lignin deposition in stone cells.

Interestingly, the lowest fruit shape index was found in Lieri Village (0.713), indicating a relatively flattened fruit shape, while other villages had values closer to or exceeding 0.8. Fruit shape is influenced by a combination of genetic factors and environmental conditions [19]. The presence of more flattened fruits in Lieri Village may be linked to local wind stress or soil nutrient imbalances, which affect hormonal regulation of cell elongation during fruit development.

4.3 Spatial Distribution and Landscape Patterns

The investigation revealed that Zui Pears in Basu County are predominantly distributed in clustered patterns along lower-altitude river valleys, with sporadic occurrences at higher elevations. This distribution aligns with the region's semi-arid monsoon climate, where water availability is more consistent and soil fertility higher in valley bottoms. Such patterns are characteristic of agroforestry systems in plateau regions, where human settlement, farming, and irrigation practices tend to concentrate around river valleys [20]. Moreover, clustered distributions may also enhance pollination efficiency and reduce fruit drop rates, which are crucial for maintaining population stability [21].

Conversely, the random distribution observed at higher elevations may result from historical planting practices and natural seed dispersal by animals. However, the higher annual evaporation rates and lower precipitation at these sites

(Basu County records evaporation rates exceeding precipitation by more than tenfold) limit water availability, leading to lower overall tree densities and potentially higher stress levels in these scattered stands.

4.4 Implications for Conservation and Sustainable Utilization

The observed variation in growth and fruit quality among different villages highlights the importance of site-specific management strategies. For example, in high-yielding areas like Ziga Village, efforts should focus on preserving existing older trees while promoting vegetative propagation of superior germplasm to maintain production stability. In contrast, areas like Lagen Village, which produce harder fruits with higher stone cell content, could be targeted for developing value-added processing industries (e.g., dried fruit, preserves) to enhance local economic returns.

Moreover, the high genetic diversity reflected by the variation in fruit shape index and quality traits underscores the need for in situ and ex situ conservation efforts. Establishing germplasm banks and seedling nurseries in lower-altitude villages with favorable growth conditions can ensure long-term preservation of Zui Pear genetic resources, especially given the threats of habitat fragmentation and genetic erosion documented in similar studies [22, 23].

References

[1] ZHANG Shaoling, XIE Zhihua. Current status, trends, main problems and the suggestions on development of pear industry in China [J]. Journal of Fruit Tree, 2019, (08): 1067-1072.

[2] Wei Wendong. World pear cultivation history, status quo and development [J]. Foreign Agronomy (Fruit Tree), 1992, (04): 10-14.

[3] Liu Yu. Effects of different fertilization treatments on growth, fruit quality and soil multifunctionality of pear trees in Linzhi City [D]. Xizang College of Agriculture and Animal Husbandry, 2024.

[4] JIAO Huijun, DONG Ran, DONG Xiaochang, RAN Kun, WANG Hongwei, GUAN Qiuzhu, WEI Shuwei. Comprehensive evaluation on fruit traits of local pear germplasm resources in Shandong [J]. Journal of Fruit Tree, 2024, (02): 201-215.

[5] BAI Mudan, FU Baochun, HAO Guowei, ZHANG Xiaowei, YANG Sheng, WANG Yanping, ZHU Kai. Overview of pear germplasm resources and research progress in Shanxi Province [J]. Journal of Fruit Tree Resources, 2021, (05): 1-4.

[6] LU Guilong, Dai Angguo, CUI Yongning, ZHANG Kai, TUDAN Jige, LI Yanfeng. Current Situation and Prospects of Pear in Xizang [J]. Xizang Agricultural Science and Technology, 2018, (03): 68-71.

[7] Yan Wenjing. Comprehensive evaluation of fruit quality traits of 107 local pear germplasm resources in Shandong province [D]. Shandong Agricultural University, 2022(01).

[8] JIA Qiangqiang, WEI Zhiran, HUANG Xihao, SONG Jian, ZHANG Kai, LI Yanfeng. Preliminary Discussion on Grape Planting Technology in Facilities in Qamdo, Xizang [J]. Xizang Agricultural Science and Technology, 2021, (02): 52-54.

[9] Yan Fei. Research of technology and methodology of forest resource inventory [D]. Beijing Forestry University, 2014(12).

[10] Rao Yuanlin. Performance and Evaluation of Characters of Five Pear Varieties fromJapan and Korea in Ya'an of Sichuan [D]. Sichuan Agricultural University, 2012(06).

[11] LI Hongchao. The Performance of Six Introduced Pear Varieties in Mengjin Luoyang [D]. Henan University of Science and Technology, 2011(09).

[12] FAN Xiaoyu, WU Wenyong, XIAO Juan, WANG Linlin. Effects of different lower irrigation limits on the growth and yield of pear trees [J]. Shanxi Water Resources, 2021, (06): 33-36+49.

[13] Wang Linlin. Study on the effects of different drip irrigation modes on soil moisture and fertilizer distribution and fruit tree growth in pear orchards [D]. Taiyuan University of Technology, 2021(01).

[14] SUN Jinhua, TIAN Chaoyang, ZHENG Xiaojun, ZHANG Ling. The division of vertical climatical zone and the analysisof temperature factors of broadleaved evergreen plantsin the south slop of funiu mountain [J]. Henan Science, 2014, (06): 1015-1019.

[15] Li Yueyao. Ecological stoichiometric characteristics of woody plants in the vertical climate zone of Sejila [D]. Xizang College of Agriculture and Animal Husbandry, 2023(06).

[16] MA Xingxiang, CHEN Lei, WANG Helin, DING Wenkui, YANG Fulin. Relationship between dry matter accumulation of spring wheat and the water and thermal condition in high altitude area [J]. Research on Agriculture in Arid Regions, 2013, (01): 52-56.

[17] SHEN La, WANG Wanzhou, ZHOU Jisheng, ZHOU Zhonglei, ZHANG Yaofeng. Exploration of the causes and prevention of apple shrinkage in western Henan in 2018 [J]. Fruit tree practical technology and information, 2019, (05): 41-43.

[18] Zeng Xiuli. Studies on the effects of habitats to sweet orange /Citrussinesis (.) Osbeck/ fruit texture [D]. Sichuan Agricultural University, 2007(02).

[19] Gao Huijun, Li Peng, Dong Tao. An overview of factors related to the development of fruit shape [J]. Journal of Tropical Biology, 2016, (02): 279-284.

[20] FENG Ming, LIU Haiqing, ZHANG Shaoshuai, TIAN Tong. Research on the Development Strategy of Thermal Industry in the Dry-Hot Valley Region of China [J]. Tropical Agricultural Science.

[21] YAO Huifang, LU Jie, WANG Chao, CHEN Kang, QU Xingle, ZHANG Duo. Spatial Pattern and Correlation of Dominant Plants in Pinus armandii Forestin Bomi Gang Township [J]. Journal of Northwest Forestry College, 2021, (04): 110-117.

[22] XIE Wendong, SONG Kai, ZHU Lei, FANG Yun, MIN Zhenglong, SUN Yuehua. Habitat Fragmentation and Protection Gap Analysis of Sichuan Treecreeper Certhia tianquanensis [J]. Journal of Zoology, 2024, (06): 817-827.

[23] Masahiro Akimoto, Keiko Morishima. Genetic erosion and habitat destruction of wild rice caused by gradual seepage of cultivated rice [J]. Agricultural Archaeology, 1998, (01).