agronomy

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Screening Optimal Oat Varieties for Cultivation in Arid Areas in China: A Comprehensive Evaluation of Agronomic Traits

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Abstract: This study was undertaken to identify oat (*Avena sativa* L.) varieties optimal for cultivation in the Jiuquan region, China, in 2021. A selection of 27 domestic and international oat varieties were analyzed, considering ten key agronomic traits, including plant height, stem diameter, spike length, leaf width, and yield. Employing methods such as cluster analysis, principal component analysis, and grey correlation degree, a comprehensive evaluation was conducted. The principal component analysis distilled the ten indicators to three core components. The most influential factors in the first principal component were plant height, ear length, and hay yield, while leaf length and leaf area index were the highest contributors to the second component. The stem-to-leaf ratio emerged as the principal indicator in the third component. The cluster analysis resulted in the classification of the 27 oat varieties into 3 categories. Following a comprehensive evaluation through the grey correlation degree and principal component analysis methodologies, we found that the oat varieties Sweety 1, Fuyan 1, Dingyan 2, Baler, Quebec, and Longyan 2 received the highest scores. These varieties, hence, appear to be the most suitable for cultivation and promotion in the Jiuquan region. This study thus provides invaluable insights into oat cultivation practices, offering guidance for farmers, agricultural policymakers, and future research in the field.

Keywords: oat; variety screening; comprehensive evaluation; Jiuquan area

Citation: Wang, G.; Xu, H.; Zhao, H.; Wu, Y.; Gao, X.; Chai, Z.; Liang, Y.; Zhang, X.; Zheng, R.; Yang, Q.; et al. Screening Optimal Oat Varieties for Cultivation in Arid Areas in China: A Comprehensive Evaluation of Agronomic Traits. *Agronomy* **2023**, *13*, 2266. https://doi.org/10.3390/agronomy13092266

Academic Editor: Jerzy Henryk Czembor

Received: 7 August 2023
Revised: 21 August 2023
Accepted: 26 August 2023
Published: 29 August 2023

1. Introduction

Oats (*Avena sativa* L.) serve as an annual forage grass and are greatly valued for their nutrient-rich grain, robust adaptability, high yield, and large market demand [1]. Primary use of oats was for animal feeding, whereas today, oat grains have become a part of the human diet [2]. They represent a potential crop for diverse terrains including dry land, barren land, alkaline soil [3], and cultivated land, enhancing the ecological function of farmland and grassland while improving farmers' income [4]. In China, the primary oat producing regions encompass provinces such as Jilin, Inner Mongolia, Shanxi, Hebei, and Gansu [5].

Situated in the Hexi Corridor at the western edge of Gansu Province, Jiuquan, a renowned Gobi oasis, possesses exceptional ecological function and geographical advantages [6,7]. It covers a vast land area of 194 billion ha^{-1}, or 42.92% of the province's total area. Of this, 2.2 million acres of arable land abound with agricultural wasteland resources [8]. The region is replete with light, heat, and water resources and is optimally suited for large-scale mechanized farming [9]. These attributes underpin Jiuquan's role as a major grain base and principal forage producing region in Gansu [10,11]. In recent years, the region has focused on diversifying its agricultural output, integrating grain, cash, and feed crops into an efficient planting system [12–14].

Nevertheless, there is a noticeable lack of high-quality oat varieties in Jiuquan, which contributes to a decline in yield and quality [12]. As oat varieties differ greatly in their adaptability to varying environments, there is a pressing need for comparative variety experiments to select those oats that promise high yield and quality in Jiuquan's unique ecological context [11,13].

Significant research has been conducted on oat botanical traits, yield cultivation measures, sowing and cutting periods, mixed sowing *Taik* niques, silage *Taik* niques, and stress resistance [14–19]. Introduction experiments across various Chinese regions have highlighted the significant differences in agronomic traits and quality performance among oat varieties under differing ecological conditions [20–22]. Such findings underline the necessity for comprehensive evaluations of oat varieties for different environments [23–27].

To identify the most suitable feed oat varieties for cultivation in the Jiuquan area, we gathered 27 domestic and international oat varieties for evaluation. Ten indices for each variety, including plant height, stem diameter, tillers, ear length, leaf length, leaf width, leaf area index, fresh grass yield, dry grass yield, and stem-to-leaf ratio were measured. This data were then analyzed using cluster analysis, grey correlation degree, and principal component analysis to provide a theoretical basis for variety introduction and promotion.

2. Materials and Methods

2.1. Research Area Description

The study was conducted at the research base of Jiuquan Agricultural Science Research Institute (39°75′ N latitude, 98°51′ E longitude), situated 1453 m above sea level. This region, a temperate arid irrigated agricultural area, experiences an average annual sunshine duration of 3174 h, an average annual temperature of 7.5 °C, an average daily temperature range of 14.4 °C, and an annual accumulated temperature of 4902.9 °C. The average annual precipitation is a mere 85.3 mm, while the average annual water surface evaporation is 2261.3 mm. The frost-free period extends over 150 days. The test site soil is classified as irrigated desert soil, with a pH of 7.8, alkali-hydrolyzable nitrogen at 32.6 mg·kg^{-1}, organic matter content at 15.1 g·kg^{-1}, available potassium at 116 mg·kg^{-1}, and available phosphorus at 27.2 mg·kg^{-1}. The site was previously used to cultivate corn (*Zea mays*).

2.2. Test Materials

We sourced 27 oat varieties both domestically and internationally, encompassing 13 domestic varieties and 14 foreign varieties. Table 1 lists the tested varieties and their origins.

Table 1. The sources of 27 oat varieties.

Code	Varieties	Sources of Varieties	Code	Varieties	Sources of Varieties
1	Taik	USA	15	Qingyan 2	Qinghai, China
2	Magnum	Australia	16	Qinghai 444	Qinghai, China
3	Monika	Canada	17	Baler	Canada
4	Fuyan 1	Gansu, China	18	Monida	USA
5	Fuyan 2	Gansu, China	19	Forge plus	Canada
6	Sweety	Canada	20	Haymaker	Canada
7	Longyan 1	Gansu, China	21	Titan	USA
8	Longyan 2	Gansu, China	22	Jiayan 2	Canada
9	Longyan 3	Gansu, China	23	Bianfeng	Canada
10	Quebec	Gansu, China	24	Souris	USA
11	Dingyan 2	Qinghai, China	25	Charm	USA
12	Dingyan 1	Gansu, China	26	Qiangshou	Canada
13	Baiyan 2	Jilin, China	27	Dingyou 8	Gansu, China
14	Qingyan 1	Qinghai, China			

2.3. Experimental Design

We adopted a randomized block design with three replications. Row spacing was set at 20 cm, with a community area of 3 m × 5 m (15 m^2). Sowing occurred on 25 March 2021, in conjunction with soil preparation and application of 300 kg ha^{-1} diammonium phosphate compound fertilizer. Manual trenching was used for drilling at a depth of 3–5 cm, and a seeding rate of 150 kg ha^{-1} was maintained. Field management followed standard practices post-emergence. Throughout the growth period, we performed irrigation five times and applied 225 kg ha^{-1} of urea during the jointing period. When each variety's growth period reached the filling stage, from 22 June to 15 July, we gradually cut and tested for yield.

2.4. Measurement Indicators and Methods

2.4.1. Observation of Reproductive Period

We observed the emergence, tillering, jointing, booting, flowering, filling, and maturity periods, as well as the total duration of the growth period (from emergence to maturity). The recording standard was set based on the date when 50% of the observation indicators for each growth period were achieved.

2.4.2. Determination of Agronomic Traits

Before cutting, we randomly selected ten plants situated 0.5 m from each plot edge. Using a ruler, we measured natural height, leaf length, and leaf width, while a Vernier scale was used for stem diameter. The number of tillers and leaves were counted, and we took the middle part excluding 0.5 m on all sides of the plot. A stubble length of 5 cm was maintained during complete cutting, and the fresh weight was measured. We took a 1 kg sample for leaf, stem, and ear separation, blanched it at 105 °C for 30 min, dried it at 65 °C to constant weight, weighed it separately, calculated the stem-to-leaf ratio, and converted it into dry matter yield.

2.5. Data Analysis

2.5.1. Grey Correlation Analysis and Cluster Analysis

In line with the grey correlation theory [4,25], we considered the plant height, stem diameter, ear length, leaf number, leaf length, leaf width, leaf area index, fresh grass yield, dry grass yield per 1/15 ha, and stem-to-leaf ratio of the 27 varieties as a whole for comprehensive evaluation and ranking.

For cluster analysis, we employed the method outlined by TongY. [26].

2.5.2. Principal Component Analysis

The method of principal component comprehensive evaluation was in accordance with [24]. We utilized SPSS 23 statistical software to standardize the data using operational description statistics and subjected the standardized data to dimensional reduction for principal component analysis. The principal components were arranged in an extraction table according to the eigenvalues from largest to smallest, and based on the eigenvalues λ where the number of principal components was greater than 1. The principal component coefficient was calculated as the square root of the load vector of each variable factor divided by the eigenvalues of each independent component, ti = ai/λ I (i = 1,2). We computed the comprehensive score for each variety, as depicted in the following formula:

$$Q = (F1 \times W1 + F2 \times W2 + \ldots + Fi \times Wi/(W1 + W2 + \ldots Wi)) \quad (1)$$

where W_i denotes the variance contribution rate, and F_i represents the sum of the eigenvectors corresponding to the eigenvalues.

Using the factor load vector ai and the principal components' characteristic roots λi, the principal component coefficient was calculated. From the functional expressions of the first three principal components are:

First Principal Component Score

F_1 = 0.833ZX1 + 0.771ZX2 + 0.841ZX3 − 0.644ZX4 − 0.108ZX5 + 0.742ZX6 − 0.065ZX7 + 0.717ZX8 + 0.811ZX9 + 0.077ZX10

Second Principal Component Score

F_2 = 0.314ZX1 + 0.290ZX2 + 0.242ZX3 + 0.704ZX4 + 0.972ZX5 − 0.091X6 + 0.735ZX7 + 0.059ZX8 − 0.067ZX9 − 0.051ZX10

Third Principal Component Score

F_3 = −0.110X1 − 0.056ZX2 − 0.278ZX3 − 0.055ZX4 − 0.076ZX5 − 0.238ZX6 + 0.314ZX7 + 0.492ZX8 + 0.131ZX9 + 0.834ZX1

3. Results

3.1. Performance of the Reproductive Period

Various oat varieties emerged 24 to 28 days post-sowing (Table 2). Varieties such as Jiayan and Longyan 2 sprouted first on 18 April, followed by Taik, Magnum, Monica, Qingyan 1, and Qinghai 444 four days later, on 22 April. The reproductive period varied between 89 and 110 days, with Charm having the longest at 110 days, and Taik and Mondragon being the earliest to mature with the shortest reproductive period of 89 days. The early maturing varieties include Taik, Magnum, Souris, and Qinghai 444, each having a growth period of $\leq$ 90 days. The medium maturing varieties, which include Monica, Baiyan 2, Qingyan 1, Qingyan 2, Meida, and Qiangshou, have a growth period of $\leq$96 days, and the remaining 17 varieties fall under the late-maturing category.

Table 2. Growth period of different oat varieties.

Variety	Sowing Date	Seeding Date	Tillering Stage	Booting Stage	Flowering Period	Pustulation Period	Mature Period	Growth Stage
Taik	4/22	5/12	5/20	5/26	6/10	6/20	7/19	89
Magnum	4/22	5/13	5/20	5/26	6/10	6/22	7/19	89
Monika	4/22	5/7	5/26	6/10	6/20	6/30	7/25	95
Fuyan 1	4/20	5/5	5/25	6/9	6/25	7/10	8/2	105
Fuyan 2	4/20	5/5	5/24	6/9	6/23	7/8	7/31	103
Sweety	4/20	5/5	5/25	6/9	6/25	7/10	8/2	105
Longyan 1	4/20	5/7	5/22	6/5	6/20	7/5	7/27	99
Longyan 2	4/18	5/6	5/25	6/8	6/21	7/6	7/29	103
Longyan 3	4/18	5/9	5/24	6/8	6/22	7/8	8/1	106
Quebec	4/20	5/8	5/24	6/4	6/20	7/5	7.26	98
Dingyan 2	4/20	5/9	5/26	6/15	6/25	7/4	7/29	101
Dingyan 1	4/21	5/9	5/25	6/9	6/23	7/5	7/30	101
Baiyan 2	4/21	5/11	5/26	6/5	6/20	6/30	7/25	96
Qingyan 1	4/22	5/8	5/25	6/4	6/18	6/29	7/23	93
Qingyan 2	4/20	5/9	5/25	6/6	6/20	6/30	7/24	96
Qinghai 444	4/22	5/11	5/23	6/3	6/15	6/23	7/20	90
Baler	4/21	5/12	5/27	6/9	6/22	7/10	8/1	103
Monida	4/21	5/11	5/25	6/8	6/20	6/29	7/25	96
Forge plus	4/19	5/13	5/26	6/10	6/22	7/7	7/28	101
Haymaker	4/19	5/7	5/25	6/9	6/21	7/10	8/3	107
Titan	4/20	5/9	5/24	6/7	6/19	6/29	7/25	97
Jiayan 2	4/18	5/6	5/24	6/6	6/20	6/28	7/24	98
Bianfeng	4/19	5/6	5/22	6/5	6/20	6/28	7/24	97
Souris	4/21	5/6	5/25	6/3	6/16	6/24	7/19	90
Charm	4/19	5/6	5/27	6/20	7/4	7/12	8/6	110
Qiangshou	4/21	5/12	5/25	6/13	6/25	7/1	7/24	95
Dingyou 8	4/17	5/8	5/24	6/8	7/1	7/10	7/25	100

3.2. Evaluation of Main Agronomic Traits

Sweety 1 and Dingyan 2 stood out with the tallest plant height, ranging from 153 to 158 cm. Varieties with the longest spike length, between 30 and 40 cm, included Fuyan

1, Sweety 1, Dingyan 2, Baler, and Haymaker. Contrarily, Taik, Mondragon, Monica, and Leader showcased the shortest spike length, falling between 13–14 cm. The leaf area index varied among the 27 oat varieties, with Monica exhibiting the lowest and Baiyan 2 the highest, as detailed in Table 3. Longyan 3 boasted the highest fresh grass yield of 98,883 kg ha^{-1}, whereas Taik and Magnum yielded the least fresh grass, ranging from 42,000 to 15,000 kg ha^{-1}. The highest hay yield was recorded by Dingyan 2 at 22,452.9 kg ha^{-1}, and Taik reported the lowest at 9622.8 kg ha^{-1}. As the protein content in leaves is significantly higher than stems and enhances palatability, the stem-to-leaf ratio is a crucial quality indicator for oats. According to the table, Souris and Sweety 1 displayed the lowest stem-to-leaf ratios of 1.82 and 1.93, respectively. In contrast, Magnum and Forge plus had the highest ratios of 3.84 and 3.81, respectively, indicating a relatively larger stem proportion.

Table 3. The properties of different oat varieties.

Varieties	Plant Height (cm)	Stem Diameter (cm)	Tiller Number	Spike Length (cm)	Leaf Area Index (%)	Stem-to-Leaf Ratio (cm)	Hay Yield kg/ha
Taik	66.2	0.3	2.6	13.8	3.39	3.51	9622.8
Magnum	86.3	0.5	2.0	13.9	8.87	3.84 *	11,124.3
Monika	69.0	0.3	3.0	13.4	2.48	2.75	20,160.75
Fuyan 1	138.8	0.6	1.4	32.0	5.53	2.13	21,689.55
Fuyan 2	135.4	0.5	2.0	23.2	6.19	2.22	19,511.25
Sweety	153.4 *	0.6	0.8	39.6 *	7.21	1.93	19,622.85
Longyan 1	134.4	0.5	1.0	21.6	4.61	2.58	18,277.5
Longyan 2	145.8	0.5	1.6	25.6	6.95	2.73	21,045.15
Longyan 3	113.6	0.5	1.0	20.6	5.07	2.35	21,655.35
Quebec	135.4	0.5	2.2	26.9	10.40	2.01	20,976.6
Dingyan 2	158.4 *	0.5	1.0	30.4	6.36	2.37	22,452.9
Dingyan 1	126.0	0.5	1.4	21.4	5.55	2.45	17,293.65
Baiyan 2	133.0	0.5	2.4	26.0	10.18 *	3.56	16,756.35
Qingyan 1	132.0	0.6	3.2 *	25.2	7.35	3.13	14,265
Qingyan 2	114.6	0.4	2.0	20.5	7.03	1.99	16,524.75
Qinghai 444	121.8	0.4	1.6	22.2	5.10	3.37	13,929.6
Baler	139.8	0.6	0.6	32.6	5.96	2.27	22,164.45
Monida	115.0	0.5	2.4	17.6	8.23	2.74	15,387.6
Forge plus	111.8	0.4	1.2	16.9	7.20	3.81 *	21,719.1
Haymaker	129.6	0.6	0.8	27.4	5.02	1.73	18,551.1
Titan	138.0	0.5	1.8	22.8	9.15	3.01	19,006.05
Jiayan 2	131.4	0.5	2.0	23.2	8.37	2.46	17,764.95
Bianfeng	107.0	0.5	1.8	21.5	10.53 *	2.25	17,978.85
Souris	86.8	0.3	2.6	13.8	8.97	2.68	17,996.1
Charm	98.0	0.5	1.0	19.8	5.32	1.82	20,229.6
Qiangshou	138.4	0.5	1.8	26.0	6.98	3.15	20,726.1
Dingyou 8	133.6	0.5	1.6	23.2	5.07	2.95	20,719.35

* indicate significant difference, $p < 0.05$.

3.3. Cluster Analysis of 27 Oat Varieties

Utilizing the average values of 10 parameters—plant height, stem diameter, tiller number, ear length, leaf length, leaf width, leaf area index, fresh grass yield, dry grass yield, and stem-to-leaf ratio—we constructed a dendrogram (Figure 1) using square Euclidean distance clustering and intergroup average linkage in the SPSS 23 system. The results, at 5 Euclidean distances, classified the oats into four distinct groups. Group one included Qingyan 1 and Qinghai 444, all originated from Qinhai province, China, group two encompassed Taik and Mondragon, group three consisted of 11 varieties including Souris, Dingyan 2, Quebec, Monica, Haymaker, Longyan 1, Meida, Baiyan 2, Qingyan 2, Leader, and Fuyan 2, and group four comprised 12 varieties—Longyan 3, Dingyou 8, Sweety 1, Qiangshou, Baler, Dingyan Dingyan 1, Bianfeng, Jiayan, Titan, Longyan 2, Forge plus, and Fuyan 1.

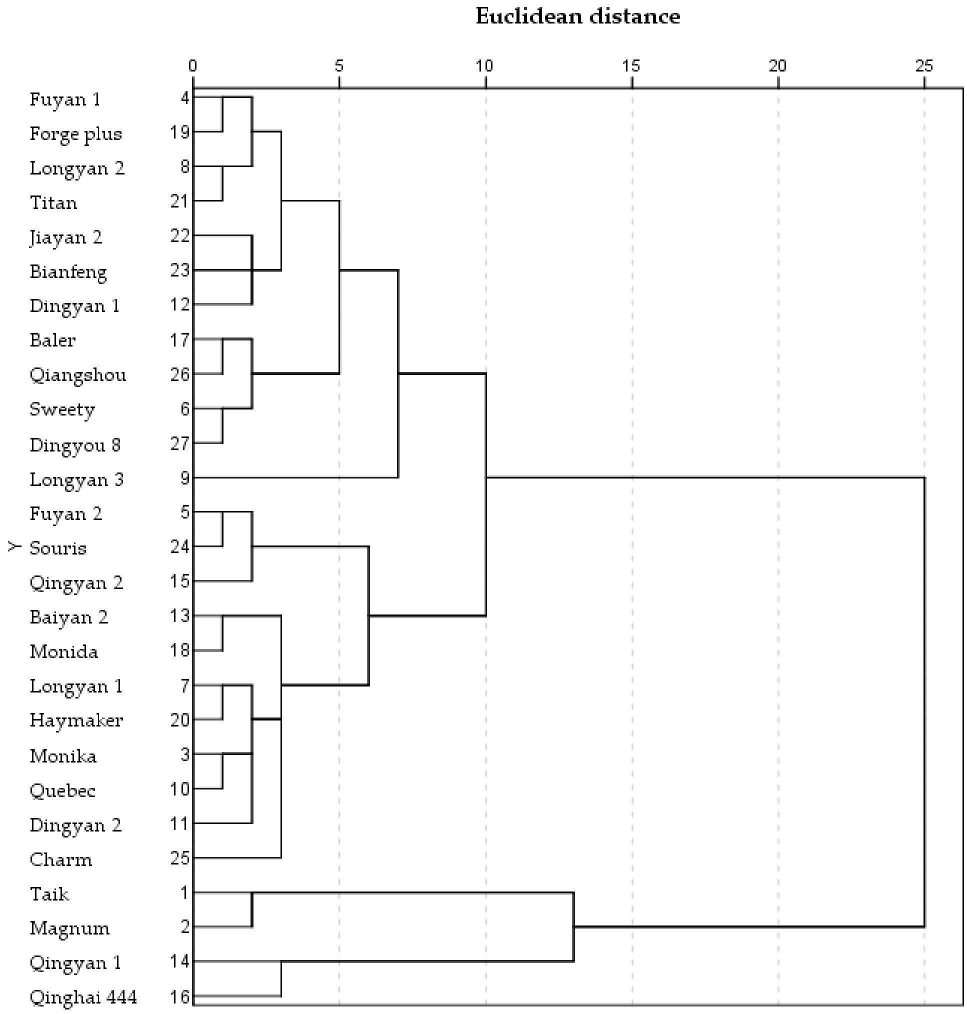

Figure 1. Dendrogram of agronomic characters by cluster analysis for 27 oat varieties.

Following cluster categorization into four groups, statistical analysis and multiple comparisons revealed that the first group's plant height, spike length, leaf area index, fresh grass yield, and dry grass yield were significantly lower than those in other groups ($p < 0.05$). However, their stem-to-leaf ratio was significantly higher. The fourth group's plant height was significantly higher than other groups ($p < 0.05$). The second group's average leaf width was notably higher than the other three groups, and their stem-to-leaf ratio was significantly lower ($p < 0.05$).

3.4. Principal Component Analysis

When assessing a variety's production performance, relying on a single attribute for evaluation is not feasible. Through dimensionality reduction, it is possible to extract a few principal components that encapsulate most of the information from the original variables. This approach allows us to gauge the importance and component of each trait in a given variety, offering a more scientific method for selecting oat varieties [28].

From Tables 4 and 5, the principal component analysis results of the tested oat varieties' agronomic traits reveal that the first principal component contributes 41.54%, the second contributes 22.41%, and the third 12.11%. The cumulative contribution of the first three principal components is 76.06%, which can essentially determine the agronomic traits of the oat variety. The major contributors to the first principal component are plant height, spike length, and hay yield. Leaf length and leaf area index significantly contribute to the second principal component, and stem-to-leaf ratio to the third. Thus, plant height, spike length, hay yield, leaf length, leaf area index, and stem-to-leaf ratio mainly determine the agronomic traits of introduced oat varieties under spring sowing conditions.

Table 4. Principal component matrix.

Item	Component		
	1	2	3
Plant height	0.833	0.314	−0.110
Stem diameter	0.771	0.290	−0.056
Ear length	0.841	0.242	−0.278
Number of leaves	−0.644	0.704	−0.055
Length of leaves	−0.108	0.972	−0.076
Width of leaf	0.742	−0.091	−0.238
Leaf area index	−0.065	0.735	0.314
Fresh grass yield	0.717	0.059	0.492
Hay yield	0.811	−0.067	0.131
Stem-to-leaf ratio	0.077	−0.051	0.834

Table 5. Variance interpretation.

Component	Eigenvector of the Correlation			Sum of Squares of Factor Loads		
	Eigenvalue	Proportion%	Pencentage	Eigenvalue	Proportion%	Cumulative Percentage/%
1	4.154	41.539	41.539	4.154	41.539	41.539
2	2.241	22.408	63.947	2.241	22.408	63.947
3	1.211	12.108	76.055	1.211	12.108	76.055
4	0.935	9.351	85.407			
5	0.712	7.116	92.522			
6	0.288	2.879	95.401			
7	0.221	2.208	97.609			
8	0.114	1.143	98.752			
9	0.107	1.071	99.822			
10	0.018	0.178	100.000			

Extraction method: Principal Component Analysis.

Using formula (1), the comprehensive score was calculated. The comprehensive score ranking is shown in Table 6, with principal component contribution rates W_1, W_2, and W_3 at 41.539%, 22.408%, and 12.108%, respectively. There are significant differences in the comprehensive ranking of each tested variety. The top five varieties in the comprehensive ranking are Sweety 1, Fuyan 1, Beile, Dingyan 2, and Longyan 2, while the last five are Tek, Magnum, Leader, Qingyan 2, and Qinghai 444.

Table 6. Score sand ranking of the principal component from different varieties.

Varieties	F_1	Rank	F_2	Rank	F_3	Rank	F	Rank
Taik	−11.120	27	−4.164	15	−0.757	20	−7.421	27
Magnum	−6.063	25	−0.877	19	0.297	10	−3.522	25
Monika	−1.158	19	−0.225	13	−1.207	24	−0.891	21
Fuyan 1	6.103	2	−0.477	16	−0.875	21	3.053	2
Fuyan 2	1.189	10	−0.719	18	−0.540	19	0.352	13
Sweety	7.358	1	0.737	9	−1.171	23	4.050	1
Longyan 1	0.139	16	−1.848	23	−0.192	16	−0.499	19
Longyan 2	2.995	6	0.246	12	0.681	7	1.817	5
Longyan 3	2.366	7	−3.225	26	3.226	1	0.856	11
Quebec	1.753	8	2.660	4	0.065	12	1.751	6

Table 6. *Cont.*

Varieties	F_1	Rank	F_2	Rank	F_3	Rank	F	Rank
Dingyan 2	3.959	5	−0.528	17	−0.516	18	1.925	4
Dingyan1	0.535	14	−1.732	22	1.505	4	0.022	17
Baiyan 2	−0.195	18	3.279	2	0.365	9	0.918	10
Qingyan No.1	−3.092	22	6.216	1	−1.640	25	−0.119	18
Qingyan No.2	−3.369	23	−0.464	27	0.026	13	−1.973	23
Qinghai 444	−4.831	24	0.489	11	−1.760	26	−2.774	24
Baler	5.322	3	−0.421	14	−0.190	15	2.752	3
Monida	−2.888	21	1.352	6	1.789	3	−0.894	21
Forge plus	0.879	12	−1.326	21	0.727	6	0.205	16
Haymaker	5.088	4	−2.562	24	−1.912	27	1.720	7
Titan	0.674	13	1.348	7	0.257	11	0.806	12
Jiayan 2	0.511	15	1.893	5	0.982	5	0.993	9
Bianfeng	−1.695	20	3.059	3	2.021	2	0.297	14
Souris	−6.807	26	0.600	10	−0.328	17	−3.593	26
Charm	−0.083	17	−3.115	25	−1.170	22	−1.149	22
Qiangshou	1.337	9	0.864	8	0.444	8	1.056	8
Dingyou 8	1.089	11	−1.062	20	−0.125	14	0.262	15

3.5. Comprehensive Evaluation of Grey Correlation Degree

Grey correlation analysis is a method that offers a comprehensive description and quantification of various factors' effects and has been widely utilized in recent agricultural research. As a variety assessment method, it provides a comprehensive and objective evaluation of multiple traits, avoiding the pitfalls of single-sided or few-trait assessments. This study employed the grey correlation analysis method to evaluate the plant height, spike length, leaf number, stem thickness, leaf length, leaf width, leaf area index, fresh grass yield, dry grass yield, and stem-to-leaf ratio of 27 oat varieties. This was done to avoid only evaluating single indicators while neglecting others.

Contrary to the equal weight correlation degree, the weighted correlation degree assigns certain weight to each index, effectively controlling the influence of local correlation points' correlation coefficient value on the overall grey correlation ranking, resulting in more reasonable outcomes. Thus, this study used the weighted correlation degree and equal weight correlation degree combined method to comprehensively evaluate the top five oat varieties. These are Sweety 1, Quebec, Bianfeng, Fuyan 1, and Jiayan (Table 7), which are derived from Canada, Gansu China, Canada, Gansu China, Canada, respectively, all suitable for widespread cultivation in the Hexi Corridor area. The lowest-ranked varieties are Taik, Mondragon, Souris, Qingyan No.1, and Qingyin 444.

Table 7. Grey correlation degree and ranking of 27 oat varieties.

Varieties	Order	Weight Correlation Degree	Order	Equal Weight Correlation Degree
Taik	27	0.3084	27	0.432
Magnum	26	0.3435	26	0.479
Monika	19	0.4160	20	0.571
Fuyan 1	4	0.4915	4	0.681
Fuyan 2	15	0.4298	13	0.599
Sweety	1	0.5186	1	0.728
Longyan 1	22	0.3997	25	0.550
Longyan 2	9	0.4646	9	0.630
Longyan 3	13	0.4389	14	0.597
Quebec	2	0.5164	2	0.724
Dingyan 2	6	0.4724	8	0.645
Dingyan 1	20	0.4127	21	0.568

Table 7. *Cont.*

Varieties	Order	Weight Correlation Degree	Order	Equal Weight Correlation Degree
Baiyan 2	8	0.4715	7	0.646
Qingyan 1	25	0.3832	24	0.533
Qingyan No.2	21	0.4110	17	0.585
Qinghai 444	24	0.3990	23	0.552
Baler	7	0.4716	6	0.651
Monida	18	0.4229	16	0.587
Forge plus	14	0.4305	18	0.575
Haymaker	12	0.4426	10	0.620
Titan	10	0.4518	11	0.614
Jiayan 2	5	0.4776	5	0.657
Bianfeng	3	0.5024	3	0.699
Souris	16	0.4284	15	0.595
Charm	23	0.3994	22	0.559
Qiangshou	11	0.4494	12	0.608
Dingyou 8	17	0.4252	19	0.575

4. Discussion

The purpose of our study was to provide an in-depth assessment of various oat varieties under identical field management conditions. We measured the environmental adaptability in our experimental area, noting the growth period of forage as a critical evaluation metric [27]. The results revealed interesting variations between oat varieties, potentially offering new insights for future agricultural strategies and improvements in yield optimization.

Of note, the Taik and Magnum oat varieties demonstrated the shortest growth period, spanning only 89 days. Conversely, the Haymaker and Charm varieties displayed a longer growth period, extending to 107 and 110 days, respectively. This difference in growth periods is indicative of the adaptability of the Charm variety to the region's environment, thus challenging preconceived notions about yield optimization and environmental adaptability. Our findings echo Xu's [29] research on different oat varieties in alpine pastoral areas, where he found inconsistent growth periods attributed primarily to the distinct genetic traits and environmental conditions of each variety. This opens the door for further investigation into how the manipulation of these genetic traits might affect oat yield optimization in different geographical areas.

Our study also investigated oat forage yield variations across different cultivation regions. It was observed that the yield significantly differed among regions, mirroring the findings by Jiang [30], who demonstrated an average oat hay yield range of 10,740 kg to 16,690.5 kg per ha across 22 different oat varieties in the Huanghuai region. In comparison, our research findings displayed hay yields per ha ranging from 9622.8 kg to 2952.9 kg. The results are a testament to the complexity of oat forage yield optimization, considering the wide yield variations across different regions. Plant height and tiller number emerged as critical indicators reflecting grass yield [31], offering potential areas for targeted interventions to improve oat forage yield.

To offer a robust analysis, our study utilized Grey Correlation Analysis, an evaluation method that quantifies the effects of various factors [32]. The method provided a comprehensive evaluation of ten indicators across 27 oat varieties, offering a holistic perspective that avoids the limitations of a one-sided assessment based on a single trait or few traits. Based on the weighted correlation degree, the top-performing oat varieties suitable for the Hexi Corridor were identified as Sweety 1, Quebec, Bianfeng, Fuyan 1, and Jiayan. These findings contribute significantly to our understanding of the most suitable oat varieties for different regions, opening up opportunities for yield optimization.

Nonetheless, it is worth noting that a discrepancy was observed when comparing the results from the Grey Correlation Analysis and the Principal Component Analysis. This discrepancy may be attributed to the different standardization methods employed by the two analytical Taik niques, underscoring the importance of considering methodological variations in interpreting findings. Despite this variation, both methods consistently ranked the Sweety 1 variety as the top performer, emphasizing its superior traits in the context of our study.

Although our study presents critical insights into oat forage yield optimization, it is important to consider the limitations. As all varieties were evaluated under the same management conditions and in the same experimental area, the results may not be generalizable to all environments. Future research should consider different geographical locations and climates to provide a more comprehensive understanding of the growth and yield of different oat varieties.

This study highlights the critical role of genetic characteristics, environmental conditions, and the choice of analytical methods in understanding the environmental adaptability and yield of different oat varieties. By doing so, it paves the way for future targeted interventions aimed at improving oat forage yield, potentially impacting agricultural practices and policies. As we look to the future, we are reminded of the broader implications of our work and how it contributes to the wider discourse on sustainable agriculture and food security.

5. Conclusions

Oat cultivation is of immense global significance, and the challenge of selecting optimal varieties for specific regions is a common concern across different ecological and geographical landscapes. This study identified key agronomic traits influencing the growth and yield of 27 oat varieties in the Jiuquan area. The most influential attributes were plant height, spike length, and hay yield. Leaf length and leaf area index were significant contributors to the second principal component, while the stem-to-leaf ratio was the primary indicator in the third component. Six varieties, Tianyan 1, Fuyan 1, Dingyan 2, Baylor, Quebec, and Longyan 2, were found to be the most suitable for promotion and cultivation in the region. The findings provide valuable insights for oat cultivation, but the specific conditions of the Jiuquan area should be considered when applying these results elsewhere.

Author Contributions: Conceptualization, G.W. and Y.L. (Yuan Li); methodology, G.W.; software, G.W., H.Z., Y.W. and Y.L. (Yuqing Liang); validation, G.W., Y.L. (Yuan Li), H.X. and X.G.; formal analysis, G.W., Y.L. (Yuqing Liang), X.Z. and Q.Y.; investigation, G.W., H.X. and X.G.; resources, G.W. and X.G.; data curation, G.W.; writing—original draft preparation, G.W.; writing—review and editing, G.W., H.Z., Q.Y. and Y.W.; visualization, G.W.; supervision, H.X.; project administration, Z.C. and R.Z.; funding acquisition, Y.L. (Yuan Li). All authors have read and agreed to the published version of the manuscript.

Funding: Natural Science Foundation of Gansu Province: 22JR5RA455, and Key Technology Integration and Demonstration for Improving Quality and Efficiency of High-Quality Forage Grass in Arid Regions of Huan County (2022YFD1602102).

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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