Screening of silage maize cultivars for their agronomic traits in Hohhot of China

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Abstract: The study was conducted to determine yield and agronomic traits of some silage corn varieties in Hohhot of Inner Mongolia Autonomous Region, China, in order to screen several suitable varieties grown as the main forage in Hohhot. The study was established to randomized complete block design pattern with three replications in irrigating conditions. In this research, agronomic traits including growing stages, days from emergence to silage harvest, plant height (cm), ear height, stalk diameter, number of green leaves, lodging rate, empty stalk rate, double strike rate, forage yield, and forage nutritive traits including crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), were determined in 34 silage corn varieties. The results showed that most of the varieties showed obvious difference among the growing stages, especially after tasseling stage. The forage yield range was from 31.21 to 80.53 T Ha⁻¹. Among all the tested varieties, a total number of 17 (ranking from 1 to 17) varieties of forage production were higher than 50 T/Ha. Combined with agronomic and forage nutritive data obtained from the study, we finally selected 5 varieties (Jilong 369, Xianyu 1580, Xianyu 1692, Jinai 130, 32D22) as the suitable varieties to promote planting in Hohhot.

1. Introduction
Livestock are an integral and vital constituent of farming systems all over the world. This industry development is consuming more and more forage. Farmers must use more concentrates than roughages due to lack of pasture area available for grazing. Forage is considered to be the most palatable animal feed resource which is highly relished by animals. Compared to labor intensive cut and carry fodder grass, corn planting can be mechanized to produce large quantities of feed and the quality can be easily controlled on farm. Also, forage corn can be harvested at any stage and fed to animals as there is little or negligible risk of oxalic acid, cyanide and prussic acid presence as that of forage sorghum [1, 2]. Moreover, silage corn contributes greatly to supplying the energy, starch, and forage neutral detergent fiber (NDF) needs of high-producing livestock, especially for dairy cows and beef, reducing purchased feed costs from expensive grain and byproduct supplements, and generating milk revenue for dairy producers. It is coveted as a forage source for ruminants around the world, because of its agronomic yield potential and energy value relative to other forage crops [3, 4]. In New York State in 2018, 445,000 acres of corn silage were harvested to produce 8,455,000 tons (USDA/NASS, 2019). Annually, 105 million Mg of fresh corn forage was harvested in the United States, on average, over the last 10 years.
[3]. What’s more, maize has become the largest cereal food crop in China since 2013, and the maize production was 215 Mt in 2014 (FAO, 2016), which accounted for more than one-third of China’s cereal production and was responsible for 21% of the global maize output [5].

However, lack of good quality and enough feed resources is one of the major factors suppressing world animal husbandry development [3, 6-9]. Approximately 90% of feed grains consumed by Japanese livestock farms are purchased from overseas [10]. In addition, the amount of corn available for trade in the United States, the largest corn exporter in the world, continues to decline (USDA2013). There is the same question in Inner Mongolia, which is one of the biggest autonomous regions (Provinces) for animal husbandry of China. Hence, an appropriate level of feeding with corn silage can therefore decrease the amount of feed grain such as a flaked corn that is required. And we need locally grown corn provide consistent feed material which can be stored over a long period as silage. However, very few high-yield and high-quality silage corn varieties are suitable for planting in Inner Mongolia, especially in the middle and west section of this autonomous region, such as Hohhot.

What’s more, over the last several years, silage corn has become an important and popular feed stuff for animal husbandry production in Inner Mongolia of China. Copious research has been dedicated to the development and evaluation to enhance the nutritive value and yield corn silage. Producing sufficient high quality forage on farms is becoming difficult given current economic and environmental pressures. Farmers are looking for good variety to improve yield and quality of their own forage to reduce the financial burden of purchasing feed off-farm. Hence, our primary objective is to summarize and discuss recent data that screen the suitable variety of silage corn, with specific emphasis on high yield, high quality, and suitable for mechanized harvest in Hohhot of Inner Mongolia, China.

2. Materials and methods

2.1. Plant materials, growth conditions
A total of 34 silage maize cultivators from different origins were used for this study. A field experiment was conducted in 2017 at Hechuang Agricultural Review Center in Hohhot of Inner Mongolia autonomous region (N 40°41′, E 111°26′, elevation 1027 m), China. The soil was yellow loam soil. The organic matter content of 0-20 cm soil layer was 17.46 g/kg; the content of total nitrogen, phosphorus, and potassium was 0.63 g/kg, 0.51 g/kg, and 17.4 g/kg, respectively. The content of alkali nitrogen, available phosphorus, and available potassium was 53.2 mg/kg, 25.1 mg/kg, 113.7 mg/kg, respectively, and the average bulk density of soil was 1.23 g/cm³. The previous crop on this field was corn.

2.2. Experimental design
The plants were planted by varieties in wide and narrow rows (width 0.6m, narrow row 0.4m) on May 8th in 2017, with density of 75,000 plants per hm², plot area 60 m². The control variety was Xianyu 335, and 4 protection lines were set around the test site. To ensure optimum growth of the plants, regular maintenance was carried out during the plant growth. Thinning of excess plants was done two weeks after planting while fertilizer (N:P:K=15:15:15) was applied two times at a rate of 600 kg/hm² on June 10 and August 10 separately. And urea was applied at a rate of 150 kg/hm² on July 20, 2017. The irrigation method is drip irrigation, and other management is the same the field.

2.3. Agronomic characters
Under field conditions, we investigated the agronomic traits including growing stage. The standard is as follows. Emergence period: the date when 50% of the number of young shoots in the whole area were unearthed up to 2 cm; Tasseling stage: the date when 50% of the entire plant's tassel spikes show the top leaves; Silking stage: the date on which 50% of the female panicles in the whole region took filaments; Silage harvest time: the date of the harvest day, generally at the day when the grain milk line reaches 1/2; Days from emergence to silage harvest (days): days from sowing to harvest.

The following data were taken at sampling time using standard ruler and weighing machine. Plant heights of 10 plants from each variety were measured from ground surface to top of tassel and mean
values were calculated. Ear height of 10 plants from each variety were measured from the ground surface to the inflorescence of the panicle and mean values were calculated. A carpenter’s tape was used for measuring the above heights. The stalk diameter of the middle stem in the third internode was measured by a vernier caliper. The number of green leaves of single plant was counted at harvest time when measuring plant height. The lodging rate was percentage of plants with an inclination greater than 45 degrees and broken below the ears in the whole plot area. The empty strike rate was the percentage of plants with less than 20 seeds ear and bearing ear in the whole plot area. The double strike rate was the percentage of plants with double ears (more than 20 seeds in the second ear) in the whole plot area. All data had 3 replicates.

When harvest, the whole plants were castrated from 20 cm above the ground. The fresh weight was weighed immediately according to the plot after harvest to get the biological yield of the plot. After obtaining biological fresh yield, the samples were then cut and dried by putting it into paper bags and placed in an oven at 60°C until constant weight. The dried samples were then ground by a cutting mill, with a screen of less than two mm particle size. The samples were then kept in pillboxes and stored in dry room until further analysis.

2.4. Forage nutritive value
For forage nutritive value determinations, after sampling at the harvest stage in 2017, maize plants were broken up by a straw cutter (9ZP-0.9, Liaoning, China) and dried at 105°C for 4h, then 60°C for 48 h in a forced-air oven to constant weight. The dried plant samples were ground in a mill (9FQ-235, Beijing, China) and then used a Near Infrared Spectrum (NIRS, DA7200, Switzerland) for crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) determinations.

2.5. Statistical Analysis
Statistical analyses were performed using a general linear model in in SPSS 19.0 software (IBM Company, Chicago, IL). The comparisons among varieties were made by Duncan’s multiple range tests. Statistical comparisons were significant when P < 0.05.

3. Results

3.1. The Growing stage of silage maize
As shown in table 1, we investigated the growing stages and days from emergence to silage harvest of silage maize. The emergence stage was same among all the tested varieties. It was Jintian 11 that first entered the tasseling stage and silking stage. The latest species entering the tasseling stage and silking stage were Xianyu 1692 and Xinyu 51, which was both 12 days later compared with Jintian 11. Also, Jintian 11 was the first variety to be harvested on September 2, 2017, and the days from emergence to silage harvest was only 108 days, the shortest one in growing period. The longest days from emergence to silage harvest were 130d, including Zhongxing silage 1, Dongke 301, Jinghua 8, Shenyu 33 and Xinyu 518.

| #  | Name         | Emergence stage (month/day) | Tasseling stage (month/day) | Silking stage (month/day) | Silage harvest time (month/day) | Days from emergence to silage harvest (days) |
|----|--------------|----------------------------|-----------------------------|---------------------------|--------------------------------|---------------------------------|
| 1  | Xianyu 335   | 5/17                       | 7/15                        | 7/16                      | 9/17                           | 123                             |
| 2  | Shenyu 801   | 5/17                       | 7/17                        | 7/19                      | 9/23                           | 129                             |
| 3  | Lihe 1       | 5/17                       | 7/15                        | 7/16                      | 9/10                           | 116                             |
| 4  | Beinong silage 3740 | 5/17              | 7/16                        | 7/20                      | 9/10                           | 116                             |
| 5  | Danyu 402    | 5/17                       | 7/18                        | 7/17                      | 9/23                           | 129                             |
| 6  | Dongyu 120   | 5/17                       | 7/20                        | 7/22                      | 9/23                           | 129                             |
| 7  | Jingke silage 205 | 5/19              | 7/19                        | 7/22                      | 9/17                           | 121                             |
| 8  | Jingke silage 301 | 5/17              | 7/16                        | 7/19                      | 9/23                           | 129                             |
3.2. The Main agronomic traits of different silage maize varieties

As shown in table 2, the plant heights of tested varieties ranged from 268.8 to 385.8 cm. The highest one was Jinai 130, and the shortest one was Jingke silage 301. The highest ear height was Xinyu 518 with the number of 196.52 cm, and the lowest one was Jintian 11 with 100.32 cm. There are 18 varieties with a plant height higher than 330cm. The stalk diameter of tested varieties ranged from 24.71 to 16.79 cm. The highest one was Jinling silage 10, and the lowest one was Jintian 11. The variety with the highest number of green leaves was Xinyu 518, the lowest one was Jintian 11, with the number of 17. There were 20 varieties with a stalk diameter higher than 21cm. When we harvested the corn, there still some green leaves on the plant. The variety with the highest number of green leaves was Xinyu 518, with 25 green leaves. The variety with lowest number of green leaves was Jintian 11, with 17 green leaves. There were 18 varieties with a number of green leaves higher than 21cm.

| #  | Name              | Plant height (cm) | Ear height (cm) | Stalk diameter (cm) | Number of green leaves | Lodging rate (%) | Empty stalk rate (%) | Double strike rate (%) |
|----|-------------------|-------------------|-----------------|---------------------|------------------------|------------------|----------------------|------------------------|
| 1  | Xianyu 335        | 362.60            | 128.70          | 19.47               | 18.00                  | 1.32             | 0.00                 | 0.00                   |
| 2  | Shenyu 801        | 347.24            | 137.58          | 19.36               | 19.00                  | 37.50            | 0.00                 | 0.00                   |
| 3  | Lihe 1            | 365.20            | 139.68          | 20.12               | 19.00                  | 1.56             | 3.00                 | 0.00                   |
| 4  | Beinong silage 3740 | 318.20         | 130.98          | 20.66               | 20.00                  | 0.00             | 0.00                 | 15.00                  |
| 5  | Danyu 402         | 345.00            | 163.54          | 23.92               | 22.00                  | 96.97            | 1.00                 | 0.00                   |
| 6  | Dongyu 120        | 336.00            | 143.20          | 22.49               | 22.00                  | 33.24            | 0.00                 | 0.00                   |
| 7  | Jintian 11        | 303.16            | 120.36          | 17.34               | 20.00                  | 0.00             | 1.00                 | 0.00                   |
| 8  | Jinyuan 15        | 284.34            | 117.88          | 19.50               | 19.00                  | 31.85            | 1.00                 | 0.00                   |
| 9  | Jintian 11        | 268.80            | 139.68          | 21.96               | 19.00                  | 0.00             | 0.00                 | 1.00                   |
| 10 | Jinyuan 15        | 232.00            | 121.50          | 22.20               | 19.00                  | 0.00             | 0.00                 | 1.00                   |
| 11 | Jintian 11        | 210.00            | 116.00          | 22.00               | 19.00                  | 0.00             | 0.00                 | 1.00                   |
| 12 | Jintian 11        | 188.00            | 116.00          | 22.00               | 19.00                  | 0.00             | 0.00                 | 1.00                   |
| 13 | Jintian 11        | 166.00            | 116.00          | 22.00               | 19.00                  | 0.00             | 0.00                 | 1.00                   |

Table 2 Main agronomic traits of the tested varieties
14 Jinai 588 359.40 124.24 22.27 20.00 0.00 3.00 0.00
15 Jinshuang 998 300.80 121.32 24.11 17.00 1.79 0.00 0.00
16 Jinling silage 10 370.00 178.34 24.71 21.00 3.95 4.00 0.00
17 Jintian 11 272.74 100.32 16.79 17.00 0.00 0.00 0.00
18 Jinyuan 15 327.20 178.34 24.71 21.00 3.95 1.00 0.00
19 Liaodan 588 304.30 128.60 22.31 20.00 0.00 4.00 0.00
20 Meifeng 969 341.20 105.48 20.00 20.00 0.00 1.00 0.00
21 SN 696 347.40 133.78 20.19 18.00 2.50 0.00 0.00
22 32D22 362.20 145.44 22.74 19.00 0.00 2.00 0.00
23 Xianyu 1580 384.40 151.90 20.95 21.00 1.32 0.00 1.00
24 Xianyu 1692 359.00 132.76 21.54 20.00 3.24 0.00 0.00
25 Dongdan 606 322.86 142.62 21.54 19.00 0.00 7.00 0.00
26 Xinzhu 2 361.20 153.18 23.28 20.00 0.00 1.00 0.00
27 Zhongxing 618 340.78 125.84 18.00 17.00 1.32 0.00 1.00
28 Zhongxing 619 368.70 163.36 22.59 20.00 9.28 4.00 0.00
29 Zhongxing silage 1 312.36 160.00 19.17 20.00 3.00 3.00 0.00
30 Dongke 301 313.40 136.20 21.97 21.00 5.10 6.00 0.00
31 KXA 4574 320.20 115.28 21.21 19.00 0.00 4.00 0.00
32 Jinghua 8 294.80 110.02 20.66 19.00 0.00 6.00 0.00
33 Shenyu 33 312.36 160.00 19.17 20.00 3.82 3.00 0.00
34 Xinyu 518 361.60 196.52 22.21 25.00 30.87 0.00 0.00
   Average 334.46 135.67 21.24 19.68 7.94 2.44 0.65
   Maximum 385.80 196.52 24.71 25.00 96.97 17.00 15.00
   Minimum 312.36 115.28 21.21 19.00 0.00 0.00 0.00
   Range 117.00 80.53 7.92 6.00 96.97 17.00 15.00
   CV(%) 9.10 15.37 8.98 7.58 239.28 417.9 417.9

The “Criteria for the Certification of Major Crop Varieties” promulgated in 2017, stipulates that the average annual rate of lodging trials of silage corn is ≤8.0%, for silage corn suitable for mechanized harvesting, the sum of lodging rate is ≤3.0%. In our research, the varieties with a lodging rate of more than 8% included danyu 402, shenyu 801, dongyu 120, jinke silage 301, xinyu 518, and zhongxing silage 1, the lodging rates were 96.97%, 37.5%, 33.24%, 31.85%, 30.87%, and 9.28%, respectively. Because of the high lodging rate, these varieties were not suitable for local planting in Hohhot. And some varieties lodging rates were lower than 8%, but higher than 3%, including Jinling silage 10, Dongdan 606, Dongke 301, Shenyu 33. So these varieties were not suitable for mechanized harvesting. Among the tested varieties, only four varieties had an empty stalk rate higher than 5%. They were Dongdan 606, Xinzhu 2, Jingke 301 and Jinghua 8, with an empty stalk rate of 17%, 7%, 6% and 6%, respectively. Only three varieties had double spike characteristics. They were Beinong silage 3740, Dongdan 606 and Xianyu 1580, with the double strike rate of 15%, 6% and 1%, respectively.

3.3. The Forage yield of the test varieties
Forage yield is an important indicator for the selection of silage corn varieties. Forage yield in corn varieties used in the study were show statistically significant differences and yields ranged from 31.21 to 80.53 T Ha-1 (Fig. 1). Among all the test varieties, Jinling silage 10 had the highest yield output, and Jingke silage 301 was the lowest one. Among the tested varieties, a total number of 17 (ranking from 1 to 17) varieties of biological production were higher than 50 Ha-1.
3.4. Correlation coefficients among yield and agronomic traits in silage harvest period

As in table 3, forage yield had a significantly positive correlation with plant height \( (r=0.584**) \) and stalk diameter \( (r=0.502**) \). Plant height was positively correlated with ear height \( (r=0.607**) \) and stalk diameter \( (r=0.466**) \). Also, there was a positive correlation between ear height and stalk diameter \( (r=0.497**) \), green leaf number \( (r=0.693**) \) and lodging rate \( (r=0.369*) \). The interesting phenomenon was the positive correlation between number of green leaves and lodging rate\( (r=0.486**) \). What's more, there was no correlation between empty stalk, double strike rate and other agronomic traits.

Table 3 Correlation coefficients among biological yield and agronomic parameters in silage harvest period.

| Indicator | V   | V1  | V2  | V3  | V4  | V5  | V6  | V7   |
|-----------|-----|-----|-----|-----|-----|-----|-----|------|
| V         | 1   |     |     |     |     |     |     |      |
| V1        | 0.584**| 1   |     |     |     |     |     |      |
| V2        | 0.338 | 0.607**| 1   |     |     |     |     |      |
| V3        | 0.502**| 0.466**| 0.497**| 1   |     |     |     |      |
| V4        | 0.049 | 0.286 | 0.693**| 0.274| 1   |     |     |      |
| V5        | -0.125| 0.035 | 0.369*| 0.192| 0.486**| 1   |     |      |
| V6        | 0.233 | -0.079| 0.079 | 0.191| 0.049| -0.178| 1   |      |
| V7        | 0.117 | -0.096| -0.007| -0.042| 0.060| -0.090| 0.164| 1    |

Note: V: Biological yield; V1: Plant height; V2: Ear height; V3: Stalk diameter; V4: Number of green leaves; V5: Lodging rate; V6: Empty stalk rate; V7: Double strike rate. * and ** means that the correlation analysis is significant at the 0.05 and 0.01 probability level, respectively.

3.5. Crude protein, neutral detergent fiber and acid detergent fiber concentrations

The silage corn varieties with higher protein and lower fiber content have good palatability. As shown in Fig. 2, the variety with the highest crude protein content is Beinong silage 3740, simultaneously with lowest NDF and medium ADF. Also, the varieties of Dongke 301, Zhongxing 618, KXA 4574, 32D22, Zhongxing silage 1, Danyu 402, Meifeng 969 and Lihe 1 also had better equality indicators.
Fig. 2 Average percentage of CP, NDF, ADF of 34 silage maize varieties at harvest time.

4. Discussion

Good silage maize has suitable growth period, higher forage yield, good nutritional quality. There were significant differences in the above characteristics among the tested varieties. Most of the varieties showed obvious difference among the growing stages, especially after tasseling. The results were in keeping with Shehzad et al [11] who found significantly taller plant in a later growing stage. The different results were possibly due to different silage corn varieties characteristic. Varieties with different days from emergence to silage harvest were suitable for different ecological areas. Usually, given the premise of normal harvest before frost, all tested varieties could be planted in Hohhot.

Good varieties determine the yield and quality of pasture. Among all the test varieties, a total number of 17 (ranking from 1 to 17) varieties of biological production were higher than 50 T Ha-1. China’s corn production occupies 17% of global maize production[12]. As the largest agricultural production area in China, the North China Plain including Inner Mongolia, supplies more than 33% of nation’s maize production [13]. And corn production has been intensively investigated in the past decades at different time and places in China [5, 8, 14-21]. Improving corn yield has always been our goal, our data about corn forage yield can enrich corn production data of Inner Mongolia of China, which will provide some references for future researchers.

Except for considering biomass, important agronomic traits related to production performance need to be considered in the selection of silage corn varieties. Among the 17 varieties, Jinling silage 10, Zhongxing silage 1, and Danyu 402 had a higher lodging rate. KXA4574, Dongdan 606, and Lihe 1 had a higher empty stalk rate. Usually, the average plant height in maize has been reported to range from 1.5 to 3 m and the effect of genetic structure is an important factor affected plant height [22]. In our trial, the plant heights ranged from 268.8 cm to 385.8 cm. The higher the plant height means the greater the yield. These results were highly consistent with previous research [9]. There was also a positive correlation between forage yield and stalk diameter. This was also confirmed by some research scholars [23]. In addition, windy weather often occurs in Hohhot especially during fall harvest season. Lodging was the main factor leading to the reduction of silage corn yield, and it also increased the cost of harvesting. Therefore, agronomic traits related to lodging resistance were factors that must be considered in screening of varieties. Hence, lodging-prone varieties were not suitable for Hohhot.

Forage nutritive value, the State Standard of the People’s Republic of China “Quality grading for silage maize” (GB / T 25882—2010) shows: silage maize is divided as three grades. The first grade requires CP (%)≥7%, NDF≤45%, and ADF≤23%; the second grade requires CP (%)≥7%, NDF≤50%, and ADF≤26%; and the third grade requires CP (%)≥7%, NDF≤55%, and ADF≤29%. Among our tested varieties, except for Dongdan 606, whose DNF was 47.55, ≤55%, the other varieties were all in
the first grade equity (Fig. 2). And there were obvious differences among the different varieties in term of CP, NDF and ADF at the harvest stages. This is highly consistent with the predecessors’ research [24, 25]. Proper nutrition is benefit for digestion of cattle and sheep, which will increase milk production of dairy cow[26, 27].

5. Conclusion
To sum up, at the foundation of forage yield, comprehensively considering the required agronomic traits and forage yield, we finally selected 5 varieties from the top 15 tested varieties by yield. According to forage nutritive data obtained from the study we conducted, the most suitable varieties for Hohhot were Jilong 369, Xianyu 1580, Xianyu 1692, Jinai 130 and 32D22.

Conflict and interest
Authors declare no conflict of interest.

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