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A STUDY ON AGRONOMIC TRAITS, YIELDS AND NUTRITIVE VALUE OF FOXTAIL MILLET [*SETARIA ITALICA* (L.) P. BEAUV.] CULTIVATED WITH UNDERGROUND WATER DRAINAGE SYSTEM IN SALINE-ALKALI SOIL IN THE HETAO IRRIGATION DISTRICT (HID) OF CHINA

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Abstract

In order to explore suitable foxtail millet (*Setaria italica* L.) varieties, important for increasing plant yields in heavy saline-alkaline soil, this study utilized saline-alkali soil in Mongolia as experiment site. Seven foxtail millet cultivars were used as experimental object, and the agronomic traits, biomass, and forage nutritive value of this crop were analysed in severe saline-alkali soil with underground water drainage system. The biomass, yields, agronomic traits, and forage quality of all the cultivars of foxtail millet were compared. Compared with the agronomic traits, forage components and nutritive value varied significantly within different growth stages. The ZZ-3 cultivar held the maximum leaf number, stem diameter, leaf area, and SPAD values. All foxtail cultivars had higher crude protein (CP), neutral detergent fibre (NDF), and acid detergent fibre (ADF) contents at the heading stage than at the other stages. The NDF and ADF of ZZ-12 (69.2% and 38.3%, respectively) were higher (p<0.05) than those of the other foxtail millet cultivars (63.8-68.9% and 35.0-35.8%, respectively) at heading. Compared with those of the other cultivars, the CP (1.29 t ha^{-1}), NDF (7.47 t ha^{-1}), and ADF (3.87 t ha^{-1}) of the ZZ-5 cultivar were more intense at heading stage. No differences in the relative forage value (RFV) were observed among the seven cultivars at harvest. The selection of a suitable cultivar of foxtail millet at harvest under a subsurface pipe drainage system can be extremely effective at improving plant production in heavy saline-alkali soil. The study provided scientific bases for the cultivation of foxtail millet in heavy saline-alkali soil of the Hetao Irrigation District.

Key words: Subsurface pipe drainage; Heavy saline-alkali soil; Millet cultivars; Agronomic traits; Relative forage value.

Introduction

With the aggregation of salinized soil area in riverain region of China, the phenomenon of high production cost and reduced benefit of foxtail millet (*Setaria italica* L.) is common. According to the current cultivation situation of saline-alkali soil in Hetao Irrigation District (HID: in China, it refers to the bend of the Yellow River and its surrounding basins.), foxtail millet suitable for salinized area must be cultivated. The study of the agronomic traits, yields and nutritive value of foxtail millet in salinized areas is very important for selecting seamless millet species (Xie *et al*., 2021), with the aim to heighten the grain output. Developing millet plants capable of growing under saline-alkali conditions for the purpose of increasing size of the millet planting area along with tapping and utilizing saline-alkali land resources are highly crucial. However, few studies have investigated the agronomic traits and nutritive value of different millet cultivars under salt stress conditions. For instance, no study has proposed suitable millet species for cultivating in saline-alkali soil.

Soil salinization is one of the most severe threats to global agriculture (Lobell *et al*., 2007, Chowdhury *et al*., 2011, Dai *et al*., 2011, Zhang *et al*., 2015), it severely restricts crop growth and productivity, especially in arid and semi-arid areas (Han *et al*., 2014, Lewis *et al*., 2019). Saline-alkali land is widely distributed around the world, spreading over in more than 30 countries on six continents, with a total area of about 956 million hectares.

In these areas, high evaporation, a shallow groundwater table and insufficient rainfall lead to increased soil salt contents (Feng *et al*., 2005, Zeng *et al*., 2016, Zhao *et al*., 2016), which subsequently lead to soil degradation. Saline-alkali land is an important cultivatable land resource with immerse potential in China but offers a hinderance to grain output if salinization excels the normal standard needed for the growth of crops (Han *et al*., 2013a, Han *et al*., 2015, Zeng *et al*., 2016, Sun *et al*., 2019). Saline-alkali soil reduces crop productivity (Li *et al*., 2019, Feng *et al*., 2019). The Inner Mongolia Hetao irrigation district is one of the three largest irigation districts in China and covers approximately 2.85×10^5 hectares (ha) of salt-affected soil (Feng *et al*., 2005), accounting for approximately 25.4% of the total area (1.12×10^6 ha) (Lei *et al*., 2011, Yao *et al*., 2013, Yao *et al*., 2014, Zhao *et al*., 2016).

A modified system for leaching salt with subsurface pipes is applied in most parts of the world with the purpose of reducing soil salinity levels and eliminating water losses to levels that are within acceptable limits for crop growth (Han *et al*., 2013b, Wang *et al*., 2013; Haj and Bouri 2018). Subsurface pipes drainage system is an effective measure of reclaiming saline-alkali soil (He *et al*., 2016). It follows the basic rule of salt movement with water through undelaying subsurface pipe. Therefore, pipe can avoid excess salt, and improve quality of saline-alkali soil. In this study, the subsurface pipe drainage system was chosen to improve millet planting in combination with saline-alkali soil in the Inner Mongolia riverain irrigation district.

In China, foxtail millet is a traditional dual-purpose crop species that is cultivated worldwide because of its relative tolerance to drought and infertility under limited rainfed conditions (Juhaimi *et al*., 2019). Whole foxtail millet plants can be used as forage because of their high forage nutritive components and value (Shao *et al*., 2014, Obeng *et al*., 2015, Machicek *et al*., 2019). Compared with other cereal crop species, millet is considered relatively tolerant to saline conditions (Machicek *et al*., 2019), making it an ideal plant species for use under these conditions. With the rapidly increasing numbers of livestock, the shortage of available forage has attracted widespread attention in recent years. Therefore, this study was devoted to evaluating the agronomic traits and yields of 7 millet cultivars at three different growth stages, probing into the nutritive component and feed value of the different cultivars at the different growth stages, and hence proposing the use of specific foxtail millet after the application of surface pipe drainage system in heavy saline-alkali soil.

Materials and Methods

Experimental site: Field experiments were conducted from June 2017 in Wuyuan County in the Hetao irrigation district (41°02′ N latitude, 108°17′ E longitude), Inner Mongolia, China. The climate of experimental area is of typical continental character, with an average temperature of 8.1℃. The mean annual precipitation is 181.5 mm, which occurs mostly during the summer months of July and August. The precipitation and temperature data during the millet growth stage (from June to October) in 2018 are provided in (Fig. 1). The soil type in the area was silty loam, and the groundwater depth at the site was 1.4 m, with a total salt content of 9.6-15.4 g kg^{-1}.

Experimental design: Surface drainage pipes were installed in the experimental field in early June 2017. The length of the pipes and slope were 80 m and 0.7‰, respectively, and the burial depths were 1.4 m and 1.8 m. Sand and gravel filter material (particle sizes < 3 cm) was filled around the pipes. In total, 22.5 t of manure applied at a rate of 300 m^3 ha^{-1} was applied before the experiment. Subsoiling was then proceeded by a deep vertical rotary tillage machine: the ridges were 1 m tall and 1.5 m wide. Mulch (80 cm wide) was spread in the field, with an interval of 60 cm between the two mulch passes. The field with irrigated with water from the Yellow River: the first irrigation depth was 50 cm, followed by infiltration 20 cm, after which irrigation was then applied to a depth of 50 cm..

The experiment was arranged as a randomized complete block design. Each treatment was replicated four times. The plot area was 32 m^2 (8 × 4 m), and the row and plant spacing were 10 cm and 50 cm, respectively. Seven foxtail millet cultivars, Zhangzagu-3 (ZZ-3), Zhangzagu-5 (ZZ-5), Zhangzagu-6 (ZZ-6), Zhangzagu-12 (ZZ-12), Zhangzagu-13 (ZZ-13), Zhangzagu-19 (ZZ-19) and Zhangzagu-20 (ZZ-20), were sown on June 9, 2018, and harvested in September. Before sowing, each plot was ploughed to a depth of 60 cm. The millet was manually sown into holes (20 seeds per hole) according to traditional methods, after which the holes were covered with fine sand. Diammonium phosphate base fertilizer was applied at 225 kg ha^{-1}, and no irrigation was applied throughout the whole growing season. A total of 315 kg ha^{-1} of urea was applied via ditches at the elongation stage. After the subsurface drainage was installed at the experimental site and the salt was leached, the soil salt content decreased to 3.3 ± 2.2 g kg^{-1}. Other management practices were the same as local agronomic practices.

Sampling and measurements: Weather data during the study in 2018 were obtained from a weather station at the experimental site. Subsequent analyses of data were based on those collected at three growth stages for each cultivar (Table 1): (1) the elongation stage, (2) heading stage and (3) harvest stage. The aboveground portions of six millet plants were collected. Three of these plants were separated into stems, leaves and panicles, which were weighed to estimate their biomass and then oven dried to a constant weight at 65℃ for 96 h. The leaf area index of the plants was measured using a plant canopy analyser (LI-COR Incorporated, Lincoln, NE, USA). The plant height was measured using a steel ruler, and the stem diameter was measured by a digital Vernier calliper. The SPAD values were determined using a Minolta SPAD-502 leaf chlorophyll meter (SPAD-502, Konica Minolta Sensing, Japan).

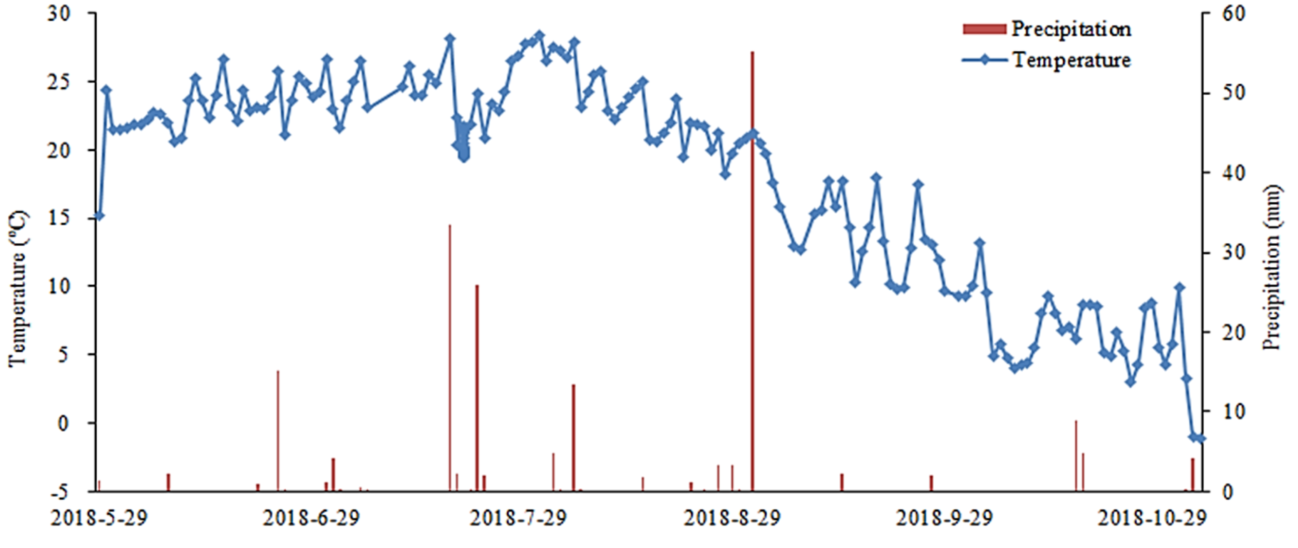

Fig. 1. Meteorological data during the study period.

Table 1. Growth period of different cultivars of foxtail millet.

Cultivar	Seeding date	Seeding	Jointing	Heading	Maturity	Growth period (days)
ZZ-3	2018.06.07	2018.06.20	2018.07.07	2018.08.09	2018.09.16	101
ZZ-20	2018.06.07	2018.06.20	2018.07.07	2018.08.09	2018.09.17	102
ZZ-12	2018.06.07	2018.06.20	2018.07.07	2018.08.09	2018.09.17	102
ZZ-6	2018.06.07	2018.06.20	2018.07.07	2018.08.09	2018.09.16	101
ZZ-5	2018.06.07	2018.06.20	2018.07.07	2018.08.09	2018.09.17	102
ZZ-13	2018.06.07	2018.06.20	2018.07.07	2018.08.09	2018.09.16	101
ZZ-19	2018.06.07	2018.06.20	2018.07.07	2018.08.09	2018.09.17	102

The crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) were determined for all plant samples. The NDF and ADF were analyzed according to the method of Van Soest *et al*., (1991). The relative feed value (RFV) refer to a forage quality index (Atis *et al*., 2012, Chen *et al*., 2015) and was calculated according to the methods of Rohweder *et al*., (1978) as follows:

$$DMI = 120/NDF \quad (1)$$

$$DDM = 88.9 - 0.779 \times ADF \quad (2)$$

$$RFV = DMI \times DDM/1.29 \quad (3)$$

where DDM is the digestible dry matter (%), DMI, the dry matter intake (%), NDF, the neutral detergent fibre (%), and ADF, the acid detergent fibre (%).

Data analysis

The original data were collected and analyzed via Microsoft Excel 2016 (Office 2016, Microsoft Corporation, Washington, USA). All the agronomic traits, yields, biomass and nutritive value data among the different cultivars and growth stages were analyzed by using Duncan multiple comparison tests at the 0.05 level of significance via the software SAS version 8.0 for Windows (SAS Institute, Cary, NC, USA). All figures were constructed by using Sigmaplot version 12.5 (Systat Software Inc., USA).

Results

Aboveground biomass and biomass allocation: The aboveground biomass for all seven cultivars of foxtail millet augmented within growth stage until the heading stage, at which point the 7 millet cultivars manifested the opposite trend from heading to maturity (Fig. 2). The highest aboveground biomass (0.85 t ha^{-1}) was recorded for ZZ-3 at the jointing stage, and the lowest (0.68 t ha^{-1}) was recorded for ZZ-20. Hence, ZZ-3 hold the best aboveground biomass performance while the ZZ-20 hold the worst. The aboveground biomass performance ranged from the best to worst at the jointing stage did not significantly differ from that of the other cultivars. The aboveground biomass ranged between 7.8 to 10.8 t ha^{-1} at the heading stage and between 3.9 to 7.1 t ha^{-1} at harvest.

The biomass of the roots, stems, leaves and panicles stood different among the 7 millet cultivars at the same growth stage (Fig. 3). The index of biomass of the millet organs first ascended rapidly but then descended slowly. The biomass of the organs of all the cultivars at the heading stage was distinct in terms of the order of leaves > stems > roots ≈ panicles and ranged from 4.9 to 6.5, 1.9 to 2.7, 1.0 to 1.8, and 0.7 to 1.7 t ha^{-1}, respectively. The biomass of the different organs at harvest varied in terms of the order of panicles > leaves > roots > stems, with values ranging from 6.3 to 11.8, 5.2 to 8.5, 4.4 to 8.5, and 3.0 to 6.2 t ha^{-1}, respectively. For each millet cultivar, the biomass of the organs was ranked top at harvest. The root, stem and leaf biomass of ZZ-5 unveiled superior performance than that of the other millet cultivars at the heading stage. Conversely, the lowest biomass at this stage was 1.0 t ha^{-1} (ZZ-20) for the roots, 1.9 t ha^{-1} (ZZ-20) for the stems and 4.9 t ha^{-1} (ZZ-6) for the leaves, respectively. ZZ-3 and ZZ-20 appeared to have the highest and lowest panicle biomass 1.7 and 0.7 t ha^{-1}, respectively. The root, stem and panicle biomass of ZZ-3 outbalanced the other millet cultivars at the harvest stage, with values (t ha^{-1}) of 8.5, 6.2, and 11.8 for the roots, stems, and panicles, respectively. Correspondingly, the lowest biomass (t ha^{-1}) at this stage was 4.4 (ZZ-5) for the roots, 3.0 (ZZ-6) for the stems, and 6.3 (ZZ-20) for the panicles. ZZ-19 and ZZ-6 manifested the highest and lowest leaf biomass 8.5 and 5.2 t ha^{-1}, respectively.

Millet yields: Compared with that of ZZ-20, the millet yields of ZZ-3, ZZ-12, ZZ-6, ZZ-5, ZZ-13, and ZZ-19 were increased 83.3%, 50.8%, 7.2%, 59.0%, 36.9% and 73.4% respectively (Fig. 4). However, these differences in yields were statistically non-significant (p>0.05).

Agronomic traits: The plant height of all 7 cultivars increased from the jointing stage to the harvest stage (Table 2). Maximum plant heights (47 and 94 cm) were recorded in ZZ-5, and the lowest plant heights (40 and 76 cm) were found in ZZ-20 at the jointing and heading stages, respectively. ZZ-20 also had the lowest plant height (92 cm) at harvest, while the greatest plant height (120 cm) at harvest was recorded for ZZ-3. The stem diameter of ZZ-3 was significantly (p<0.05) greater than the other six millet cultivars during the elongation thru harvest stages. The ZZ-3 cultivar presented the greatest leaf number, leaf area, and SPAD values. However, with the exception of the leaf area at jointing, the leaf number, leaf area, and SPAD values of ZZ-20 were much lower than those of the other cultivars.

Forage nutritive value: The forage nutritive value of all the cultivars at two growth stages are given in (Table 3). The highest CP content (12.8%) was recorded for ZZ-19, and the lowest CP content (10.5%) was recorded for ZZ-6 at the heading stage. ZZ-3 had the highest CP (10.0%) at harvest, while the lowest CP (8.4%) was recorded for ZZ-12. The CP content in all the cultivars did not significantly differ (p<0.05) at the heading stage or harvest stage; however, significant (p<0.05) differences were detected among the seven millet cultivars from the heading stage to the harvest stage. The highest NDF values were observed in ZZ-12 cultivar at the heading stage, and the NDF of ZZ-12 was significantly ($p<0.05$) higher than the NDF of both ZZ-6 and ZZ-13. ZZ-5 and ZZ-20 had the highest and lowest NDF 64.4% and 56.0%, respectively, at harvest. The ADF of the ZZ-12 cultivar was significantly higher than that of the ZZ-13 and ZZ-19 cultivars at the heading stage, whereas the ADF of all the cultivars was not significantly different at harvest.

Significant differences in the accumulation of CP, NDF, and ADF were detected among all the cultivars (Figs. 5-7). Maximum accumulations of forage nutritive components occurred at the heading stage, but their contents were decreased sharply at the harvest stage. The cultivar ZZ-5 (1.29 t ha^{-1}) presented a markedly ($p<0.05$) higher CP accumulation at the heading stage compared to ZZ-6 (0.89 t ha^{-1}), ZZ-12 (0.98 t ha^{-1}), and ZZ-20 (0.83 t ha^{-1}) cultivars. In comparison with other millet cultivars, the CP accumulation in ZZ-3 was the highest at harvest. With respect to the NDF, the ZZ-5 cultivar (7.47 t ha^{-1}) presented significantly higher values than in the other 6 cultivars (5.14-6.51 t ha^{-1}) at the heading stage. The NDF accumulation in the ZZ-3 and ZZ-19 cultivars at harvest ranged from 4.22 to 4.32 t ha^{-1}, which was significantly higher than rest of the cultivars (2.19-3.63 t ha^{-1}), except for ZZ-5 (3.99 t ha^{-1}). With respect to ADF accumulation, ZZ-5 presented significantly higher values than other six cultivars at the heading stage. The ZZ-20 cultivar showed lowest ADF, and the ZZ-3 cultivar presented a significantly higher ADF accumulation than did the other cultivars except for ZZ-5 and ZZ-19 at harvest.

There were significant changes ($p<0.05$) in dry matter intake (DMI), digestible dry matter (DDM), and RFV among all the millet cultivars (Table 4). The ZZ-13 cultivar had the highest DMI at the heading stage, while ZZ-6 showed highest DMI at harvest stage. The DDM of ZZ-13 (63.9%) and ZZ-19 (63.8%) were significantly ($p<0.05$) higher than that of ZZ-12 (59.0%) at the heading stage. The DDM of all the millet cultivars at harvest stage was not significantly different, averaging 64.4%. The RFV of ZZ-13 was 93.5% at the heading stage and was significantly higher than that of ZZ-12 (79.6); however, the RFV changed only slightly among the different millet cultivars at harvest ($p>0.05$).

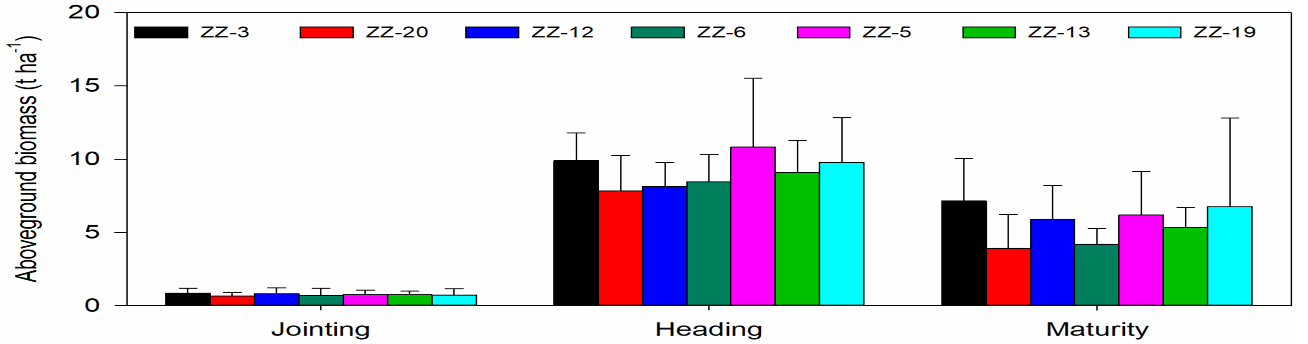

Fig. 2 Aboveground biomass of the different foxtail millet cultivars at different growth stages.

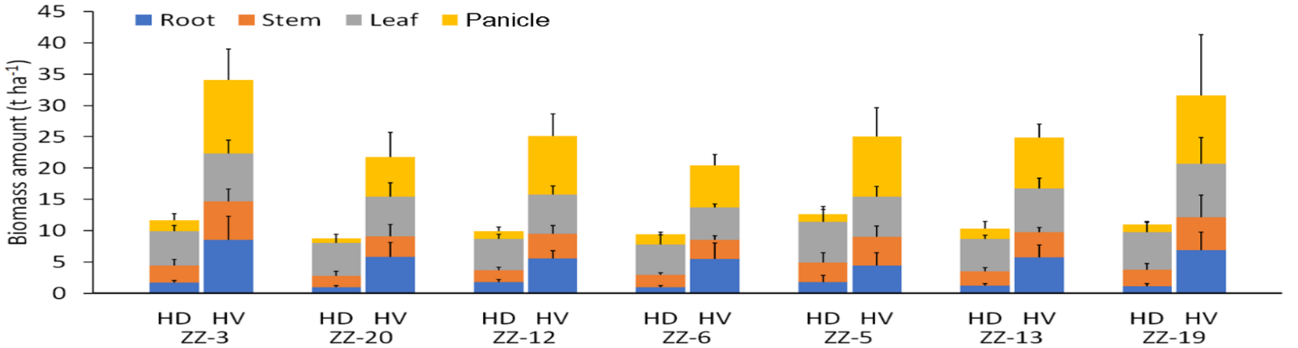

Fig. 3. Changes in the biomass (means ± SDs) of foxtail millet cultivars planted in saline-alkali soils. Heading (HD); Harvest (HV).

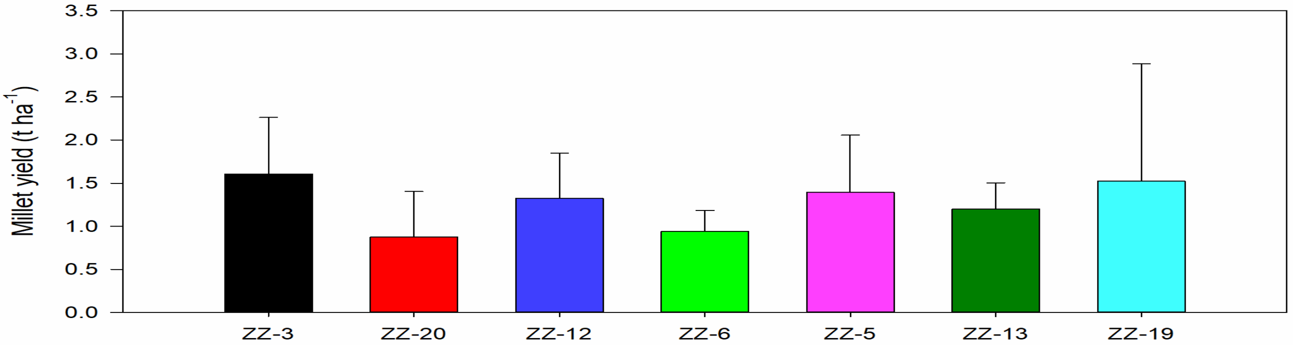

Fig. 4. Yield of different foxtail millet cultivars at harvest.

Table 2. Agronomic characteristics of foxtail millet cultivars during the growing season.

Cultivar	Jointing						
	ZZ-3	ZZ-20	ZZ-12	ZZ-6	ZZ-5	ZZ-13	ZZ-19
Plant height (cm)	41.0±4.5b	40.0±6.1b	40.0±5.4b	46.0±5.9ab	47.0±6.01a	44.0±9.1ab	44.0±5.47ab
Stem diameter (mm)	8.7±1.3a	6.3±1.1e	6.7±1.3de	7.5±1.4bc	8.0±1.1b	7.21±1.5cd	7.30±1.00bcd
Leaf number	7.0±0.6a	6.0±0.9b	6.0±0.5b	7.0±0.5a	7.0±0.6ab	6.0±1.0ab	7.0±0.58ab
Leaf area (cm^2)	56.8±12.0a	49.8±12.5bc	52.9±11.4abc	46.3±12.5c	58.5±10.9a	53.5±13.5ab	53.61±11.67ab
SPAD	39.6±4.5a	35.1±5.0a	38.8±5.6a	38.5±4.1a	37.8±5.5a	36.4±5.5a	37.9±5.16a
Cultivar	**Heading**						
	ZZ-3	**ZZ-20**	**ZZ-12**	**ZZ-6**	**ZZ-5**	**ZZ-13**	**ZZ-19**
Plant height (cm)	94.0±6.9a	76.0±17.4b	82.0±11.9b	79.0±5.5b	94.0±5.4a	79.0±12.1b	86.0±11.1ab
Stem diameter (mm)	9.6±1.90a	7.1±1.0b	7.4±1.3b	6.8±1.8b	7.4±1.3b	7.4±1.0b	7.2±1.0b
Leaf number	15.0±0.8a	14.0±0.5b	13.0±0.8b	13.0±0.7b	14.0±1.0b	14.0±0.7b	14.0±0.8b
Leaf area (cm^2)	96.9±20.0a	60.1±17.7d	84.6±23.9b	63.4±15.6cd	83.9±18.2b	61.1±18.4d	74.1±22.5bc
SPAD	49.7±10.9a	42.0±6.5c	47.8±7.4abc	48.5±6.0ab	45.5±10.8abc	43.2±10.0bc	49.1±9.7a
Cultivar	**Harvest**						
	ZZ-3	**ZZ-20**	**ZZ-12**	**ZZ-6**	**ZZ-5**	**ZZ-13**	**ZZ-19**
Plant height (cm)	120.0±13.2a	92.0±19.0b	98.0±22.4b	101.0±11.9b	110.0±18.4ab	98.0±13.8b	106.0±22.9ab
Stem diameter (mm)	8.6±1.7a	7.2±1.2b	7.0±1.8b	6.0±1.3c	7.6±1.3b	7.1±1.3b	6.9±1.4bc
Leaf number	14.0±0.5a	13.0±0.5ab	13.0±0.6ab	13.0±0.3b	13.0±0.6ab	13.0±0.5ab	13.0±0.5ab
Leaf area (cm^2)	70.3±18.4a	41.2±18.1c	59.7±21.1ab	48.9±9.6bc	56.7±17.8b	44.9±15.6c	50.4±21.3bc
SPAD	26.7±7.2a	18.5±7.1c	22.8±9.4abc	19.5±8.1c	25.2±8.7ab	22.7±7.5abc	21.6±7.9bc

Table 3. Nutritive value of foxtail millet cultivars at two growth stages (%).

Cultivars	Heading			Harvest		
	CP	NDF	ADF	CP	NDF	ADF
ZZ-3	12.1 ± 1.8a	65.6 ± 1.2ab	33.4 ± 0.7ab	10.0 ± 0.4a	59.1 ± 4.8ab	32.1 ± 2.8a
ZZ-20	10.6 ± 1.7a	65.5 ± 3.1ab	32.7 ± 1.6ab	9.3 ± 1.1a	56.0 ± 2.4b	29.9 ± 1.3a
ZZ-12	11.9 ± 1.7a	69.2 ± 2.6a	38.3 ± 4.9a	8.4 ± 1.1a	61.7 ± 3.6ab	30.7 ± 3.7a
ZZ-6	10.5 ± 0.7a	64.7 ± 2.2b	35.7 ± 1.9ab	8.8 ± 0.8a	55.8 ± 6.6b	30.6 ± 3.5a
ZZ-5	11.9 ± 1.9a	68.9 ± 1.9a	35.8 ± 3.6ab	8.8 ± 2.0a	64.4 ± 2.4a	32.7 ± 1.5a
ZZ-13	12.6 ± 0.6a	63.8 ± 2.2b	32.0 ± 2.8b	9.3 ± 1.3a	62.2 ± 1.7ab	34.1 ± 3.2a
ZZ-19	12.8 ± 2.0a	66.5 ± 1.5ab	32.2 ± 3.9b	9.9 ± 0.8a	63.9 ± 3.5a	30.0 ± 1.2a
Average	11.8 ± 0.8	66.3 ± 1.9	34.3 ± 2.2	9.2 ± 0.6	60.4 ± 3.3	31.4 ± 1.5
CV (%)	7.1	2.9	6.4	6.0	5.4	4.6

The values with different lowercase letters within the same column differ significantly at $p<0.05$. CP, NDP and ADP represent the crude protein, neutral detergent fiber and acid detergent fiber of millet at different growth periods, respectively. CV represents the coefficient of variation

Table 4. Relative forage value of foxtail millet cultivars.

Cultivar	Heading			Harvest		
	DMI (%)	DDM (%)	RFV	DMI (%)	DDM (%)	RFV
ZZ-3	1.83 ± 0.03abc	62.9 ± 0.5ab	89.3 ± 2.4ab	2.04 ± 0.17abc	63.9 ± 2.2a	101.3 ± 11.7a
ZZ-20	1.83 ± 0.09abc	63.4 ± 1.2ab	90.2 ± 6.0ab	2.14 ± 0.09ab	65.6 ± 1.0a	109.0 ± 6.4a
ZZ-12	1.74 ± 0.07c	59.0 ± 3.8b	79.6 ± 8.1b	1.95 ± 0.11abc	65.0 ± 2.9a	98.5 ± 10.1a
ZZ-6	1.86 ± 0.06ab	61.1 ± 1.5ab	88.0 ± 5.1ab	2.17 ± 0.26a	65.1 ± 2.7a	109.9 ± 17.6a
ZZ-5	1.74 ± 0.05bc	61.0 ± 2.8ab	82.5 ± 6.0ab	1.87 ± 0.07c	63.4 ± 1.2a	91.8 ± 5.2a
ZZ-13	1.88 ± 0.07a	63.9 ± 2.1a	93.5 ± 6.4a	1.93 ± 0.05abc	62.4 ± 2.5a	93.3 ± 6.2a
ZZ-19	1.81 ± 0.04abc	63.8 ± 3.1a	89.5 ± 6.3ab	1.88 ± 0.10bc	65.5 ± 0.9a	95.6 ± 6.5a

The values with different lowercase letters within the same column differ significantly at $p<0.05$. DMI, DDM, and RFA represent the digestible dry matter, dry matter intake, and relative forage value of millet at different growth periods, respectively

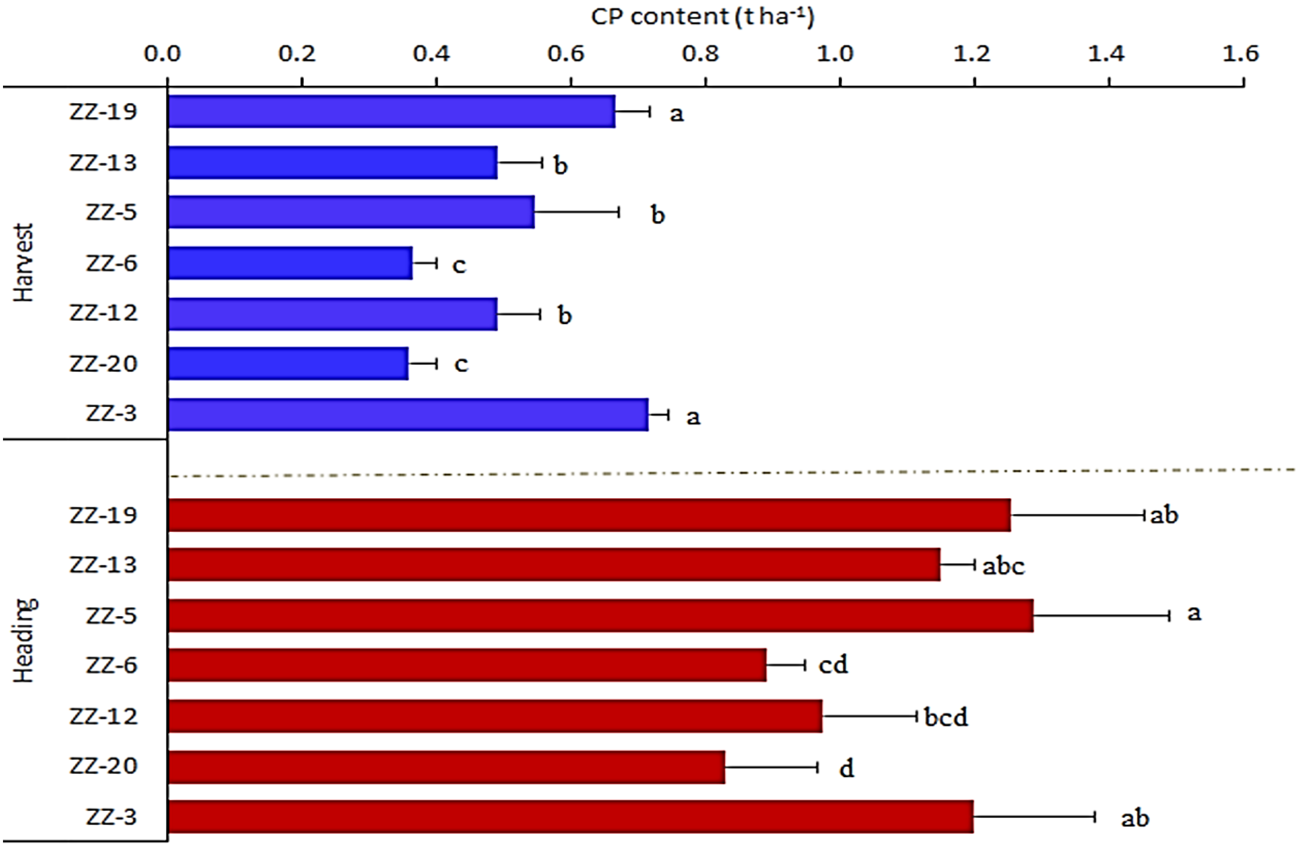

Fig. 5. Accumulation of crude protein (CP) in different foxtail millet cultivars at two growth stages. The values are the means with SD bars. The different lowercase letters to the right of the bars indicate significant differences in the accumulation of crude protein at the 5% level.

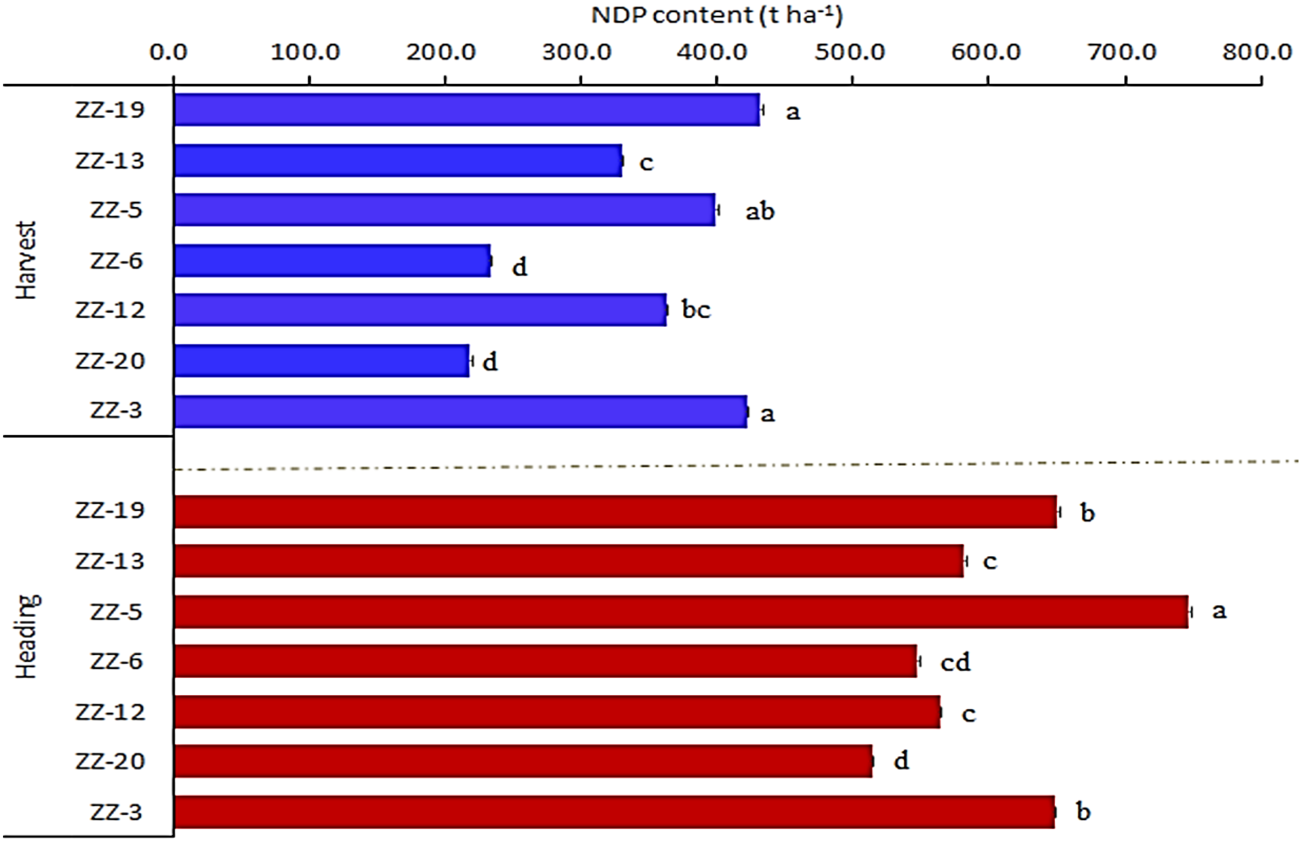

Fig. 6. Accumulation of neutral detergent fiber (NDF) in the different foxtail millet cultivars at two growth stages. The values are the means with SD bars. The different lowercase letters to the right of the bars indicate the significant differences in the accumulation of neutral detergent fiber at the 5% level.

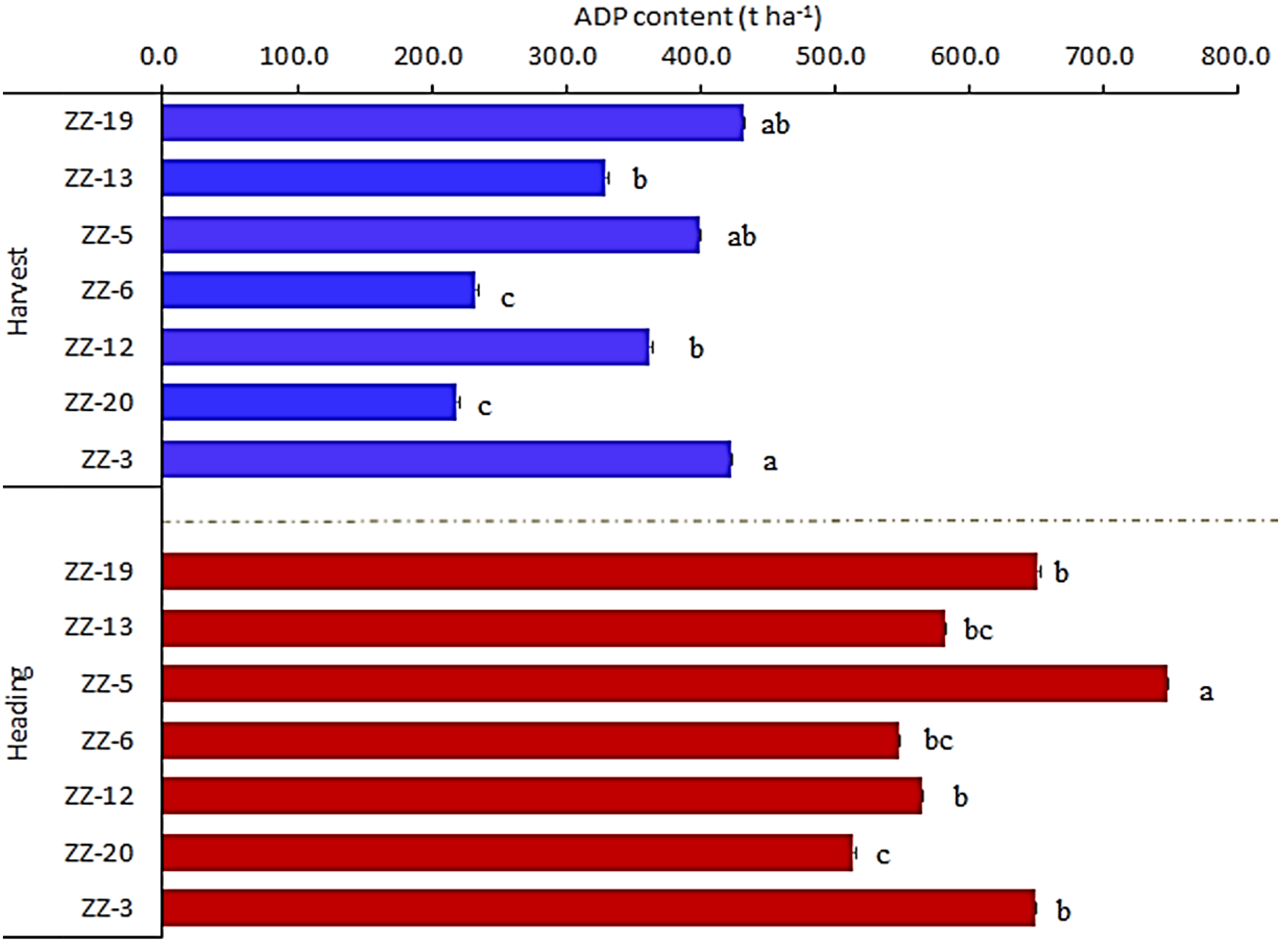

Fig. 7. Accumulation of acid detergent fiber (ADF) in the different foxtail millet cultivars at two growth stages. The values are the means with SD bars. The different lowercase letters to the right of the bars indicate significant differences in the accumulation of acid detergent fiber at the 5% level.

Discussion

After installing the underground pipe system in certain saline-alkali area, this analyzed the growth difference in terms of jointing stages, heading stages and harvest stages of all the 7 cultivars. All the cultivars expressed different growth phenomenon although being cultivated in the same environment. The results of the study showed that the agronomic traits of the different cultivars at all growth stages significantly present differences and cultivars including ZZ-9, ZZ-12, ZZ-20, and ZZ-6 were superior to the others.

Related studies (Miron *et al*., 2005) has expressed that no significant differences occur in yields among cultivars while more biomass was produced at the heading stage. This phenomenon can be explained by low temperatures, wind speed, carbohydrate loss, etc. (Miron *et al*., 2005). The average biomass of the millet cultivars in our study was lower than the previous reports (Ren *et al*., 2019). The differences in plant height and biomass can be attributed to several factors, including differences between cultivars, growth stages, and environmental conditions. Specifically, the sowing date was delayed, and heavy salt stress was also a factor. Study found that the leaf area, biomass, and rainfall received from July to August at the heading stage may attribute to the accumulation amount of forage nutritive components, which coincides with those of Miron and other researchers' studies (Miron *et al*., 2005, Miron *et al*., 2006, Aits *et al*., 2012, Lyons *et al*., 2019). As for the value of ADF and NDF, they resemble each other starkly, which can be traced in Belanger and Alix's experiment (Belanger *et al*., 2018, Alix *et al*., 2019).

From the results, it can be concluded that the installing of underground drainage system and the selection foxtail cultivars affect the yields to a certain extent. In addition, the Hetao irrigation area is an arid area with less rainfall and little inter-annual variation. Therefore, this experiment has certain guiding significance.

Conclusions

This study leverages underground drainage pipes to drain shallow water in saline-alkali soil, explores the growth characteristics, yields and nutritional value of foxtail millet in saline-alkali areas, and generate millet cultivars suitable for planting in saline-alkali soil in the Hetao area, so as to optimize the yields of foxtail millet in saline-alkali soil. The results showed that the agronomic traits of the different varieties at all growth stages were significant, with the CP, NDF, and ADF of the millet varying among the 7 cultivars used in this study. What's more, the indicators of CP, ADF and NDF for ZZ-19, ZZ-12, ZZ-20 and ZZ-6 were of higher performance compared with the rest cultivars, so these varieties are considered suitable for extensive utilization in the study area because of their high forage nutritive value.

As the saline-alkali soil features with complex background value of salt in saline-alkali soil, in order to keep the salt in the surface soil from aggregating significantly, it is necessary to ensure adequate fertilizer application and appropriate drainage to make the salt deposit to the bottom soil, in order to ensure that the growth of foxtail millet will not decrease due to the intense salt content. It can be seen that drainage is crucial for growing crops in saline-alkali soil, and proper drainage can make crops maintain a high yield in a relatively harsh environment. Therefore, millet planting in low-lying saline-alkali and should be carefully selected. From the perspective of maintaining the current maize yields and nutritional value, it is recommended to choose ZZ-19, ZZ-12, ZZ-20 and ZZ-6 when planting millet in salt-alkali soil, because these cultivars are superior to other cultivars and hold higher forage nutritional value. The underground drainage system should be used to gradually reduce the background value of soil surface salt and increase the yields steadily. On the whole, the exploration of combination with subsurface drainage systems and millet planting contributes a lot on improving heavy saline-alkali land in the Hetao irrigation district in China, providing evidence and reference for the future selection of millet cultivars to cultivate in saline-alkali area under subsurface drainage systems in Hetao area in China.

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