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Regulation of quality of naked oats under different irrigation regumes

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Article

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Abstract

Naked oat (*Avena nuda* L.) is rich in protein, fat, soluble dietary fiber and other nutrients that the human body needs; it is an important grain, feed and forage crop. Here, we investigated the effects of different irrigation and fertilization conditions on naked oat yield and quality in semi-arid regions in agriculture-pastoral zone in semi-arid areas. The experiment was carried out in a non-weighing lysimeter with four irrigation quotas (750$m^3 \cdot ha^{-1}$, 1500$m^3 \cdot ha^{-1}$, 2250$m^3 \cdot ha^{-1}$ and 3000 $m^3 \cdot ha^{-1}$) and fertilizer versus non-fertilizer to analyze the effect of different water and fertilizer conditions on the yield and quality of naked oats. The seed yield of naked oats increased as irrigation quota increased, and the highest yield of 3253 $kg \cdot ha^{-1}$ was achieved at 3000 $m^3 \cdot ha^{-1}$. An increased irrigation quota promoted the synthesis of protein, group fiber, starch and amino acid and the breakdown of fat in naked oats. Fertilizer application improved naked oat seed yield by 42.5% and facilitated an increase in the levels of protein, fat, crude fiber, starch and amino acids. This experiment provides a theoretical basis for the cultivation of naked oats in agriculture-pastoral zone in semi-arid areas.

INTRODUCTION

Oats are annual herbs of the family Gramineae and genus *Avena* which is usually subdivided into hulled oats (*Avena sativa* L.*)* and hulless naked oats (*Avena nuda* L.) (Ren, 2013). According to the 2021 FAO survey data, oats are grown globally with an area of 9.772×10^6 ha [1]. Compared with oats, naked oats possess a more reasonable level of lipids compared to crops that are mainly based on providing dietary carbohydrates. In addition to being rich in protein and fat, naked oats contain approximately 5% soluble dietary fiber (β-glucan), a key substance that aids in lowering cholesterol and thereby prevent hypertension and cardiovascular disease [2]. In addition, naked oats contain eight essential amino acids and a large number of trace elements such as Mn, Fe, Cu, Zn and Mg, which are nutritionally comprehensive and have beneficial effects on health[3].The major challenges in global agricultural production are related to water shortage and irrational fertilizer application [4,5]. China is considered one of the most water-stressed countries globally. China's water scarcity stems from a limited supply of fresh water resources, massive population base, and wastage during agricultural use [6]. Annual agricultural water use in China accounts for > 60% of the national water use, with irrigation accounting for 90%; however, the corresponding effective utilization coefficient is only 0.54. Additionally, irrational irrigation methods not only result in the wastage of valuable water resources, but can detrimentally affect the quality of crops.

Unreasonable use of chemical fertilizers is another problem in agricultural production. Notably, China's use of chemical fertilizers has been increasing at an average rate of 1.44 million $tons \cdot yr^{-1}$ [7]. Moreover, at the end of 2015, the annual chemical fertilizer use in China had peaked at 60.226 million tons, ranking among the top countries in the world in terms of fertilizer use [8]. Although the large-scale use of chemical fertilizers can increase crop yield, their excessive use poses major threats to the soil, water bodies, and the atmosphere. For example, in 2015, 6.282 million tons of nitrogen and 4.306 million tons of phosphorus were retained in the soil in China, whereas 2.471 million tons of nitrogen and 300,000 tons of phosphorus were introduced into water bodies [9].This has created a series of severe environmental problems, such as excessive groundwater nitrate content in the northern drylands, an excess of nitrogen and phosphorous content in the surface water of southern paddy fields, high quantities of agricultural ammonia in the atmosphere, and an overall decrease in soil productivity [10,11,12].We conducted an experiment in the farming pastoral ecotone in agriculture-pastoral zone in semi-arid areas northern China, where the soil is relatively barren. Although the yield of naked oats can be greatly improved in the short

term by continuous use of chemical fertilizers, this practice promotes the loss of soil nutrients. Organic fertilizer is mainly composed of animal and plant residues (such as livestock manure and crop straw) and decomposed organic materials, and pretreatment is harmless [13]. In the farming pastoral ecotone of agriculture-pastoral zone in semi-arid areas northern China, cattle and sheep dung are commonly used to produce organic fertilizer by composting. A large number of studies have shown that, compared with the use of chemical fertilizers, organic fertilizers can significantly increase the accumulation of organic carbon and nitrogen in the soil, improve its physical and chemical properties, its buffering capacity with respect to acids and bases, the activity of soil-related enzymes, and the soil microbial community, thus improving soil permeability and related metabolism. The soil environment can thus be stabilized in the range suitable for crop growth in the long term [14,15,16].

Water-fertilizer coupling refers to the effects resulting from the interplay between these two factors on plant growth and nutrient transformation—an optimal water-fertilizer ratio yields the most favorable results [17]. Studies conducted on selection of variety and yield response to different water and fertilizer conditions and nutritional value of oats, have been mainly focused on hulled oats and less on naked oats [18,19]. Therefore, this study was conducted to investigate the effect of different irrigation quotas and fertilizer management regimes on the yield and quality of naked oats and provide a theoretical basis and reference on irrigation and fertilization for the cultivation of naked oats in Agriculture-pastoral zone in semi-arid areas.

METHODS

Study site: The test site is located in the National Field Scientific Observation and Research Station for Grassland Ecology and Hydrology (41°12'10" N, 111°13'01" E) in the northern foothills of Yinshan, Halawusu, Damao Banner, Baotou City, Inner Mongolia Autonomous Region, China. This area is characterized by a mid-temperate, semi-arid continental monsoon climate.The zonal soil type of the test site is chestnut, and the soil texture is mostly sandy loam and light loam, with varying degrees of gravelization. With respect to nutrient content, soils are low in nitrogen content, very low in phosphorus content, and high in potassium content.During the experiment (April to September 2020), an ENVIS TrimeLog automatic weather station (produced by German IMKO company) was used to monitor air temperature and humidity, and precipitation. The monitoring results are shown in figure 1.

The experiment was conducted using non-weighing lysimeters constructed with reinforced concrete structures, where the soil was backfilled in layers following construction according to the original soil distribution (Figure 2). The lysimeters were arranged in two rows of 12 (N = 24), with each unit covering an area of 9.9 m^2 (4.5 m in length, 2.2 m in width). Each unit was equipped with an independent flow meter and on-off valve to accurately control the irrigation volume. To prevent the interference of natural precipitation, a rain shelter was constructed over the test site consisting of a steel frame covered with transparent panels on the roof ,which was equipped with roller wheels as well as drive units for automated deployment during rainfall.

Study design: Before experimentation, the soil in the lysimeters was sampled using an S-shaped sampling method at depths of 0–15 and 15–30 cm. Samples were transported to the laboratory to determine the following basic physicochemical properties: pH was measured using 0.01 $mol \cdot L^{-1}$ $CaCl_2$ as the leaching solution, soil organic matter (SOM) was determined using the potassium dichromate oxidation-external heating method [20], soil alkali nitrogen (SAN) was measured using the Conway method [20], soil available phosphorus (SAP) was extracted using sodium bicarbonate and analyzed using Mo–Sb colorimetry [20], and soil available kalium (SAK) was extracted using NH_4OAc and analyzed using the flame photometric method [20]. Undisturbed soils samples were collected

using the ring knife method, and field water holding capacity (FWH) and soil bulk density (SBD) were determined using the constant head method[20]. The results of the physiochemical parameters measured are shown in Table 1.

Bayou1 naked oats seed (Bayou 1 is a variety of mid maturity and high-quality naked oats developed through interspecific hybridization between skinned oats (Jizhangye 4 as the female parent) and naked oats (8061-14-1 as the male parent) at the Hebei High Cold Crop Research Institute. It was bred through sexual hybridization in 1987 and became a new product of mid maturity and high-quality naked oats) was provided by Research Institute of Pastoral Water Resources Science, Ministry of Water Resources. It is a cultivated genotype, and the collection of plant material complied with the relevant institutional, national, and international guidelines and legislation. A two-factor design was adopted for this experiment. Fertilizer application included two treatments: non-fertilization and the application of basal, starter, and topdressing fertilizers; whereas irrigation quota included four treatments: 750, 1500, 2250, and 3000 $m^3 \cdot ha^{-1}$ (N = 8 treatments; Table 2 contains more details on the study design).

In the field fertilization experiment, the soil in the lysimeter was first leveled following deep tilling to 25 cm. As the test site was located in the interlaced area of agriculture and animal husbandry, there were abundant high-quality organic fertilizers (cow and sheep manure). According to the naked oats planting practice of local growers, in this experiment, 15 kg (~15,000 $kg \cdot ha^{-1}$) of a rotted organic fertilizer was applied at the basal level to the 12 lysimeters in the four fertilization treatments. Naked oat seeds were sown by drill seeding 10 d after fertilizer application. Before sowing, 24 kg of naked oats seeds was mixed with 48 g of 25% azoxystrobin wettable powder (azoxystrobin wettable powder; Jiangsu Dongbao Pesticide Chemical Company; Jiangsu; China) to prevent smut. The seeds were sown at 3 cm depths, with a row spacing of 25 cm, where 1 kg of seeds (100 $kg \cdot ha^{-1}$) was sown in each unit. Next, 0.15 kg (150 $kg \cdot ha^{-1}$) of starter fertilizer diammonium phosphate (diammonium phosphate; Jiangsu Dongbao Pesticide Chemical Company; Jiangsu; China) was evenly applied to the 12 corresponding lysimeters, and the soil was then mulched to retain moisture. Topdressing was carried out twice throughout the experimentation process (at jointing period and filling period), during which 0.1 kg (100 $kg \cdot ha^{-1}$) of urea (urea; Jiangsu Dongbao Pesticide Chemical Company; Jiangsu;China) was evenly applied to the 12 lysimeters.

Irrigation was started at the time of sowing, where the four possible treatment conditions were applied ten times over the five reproductive stages—sowing-seedling emergence, trilobal stage, Jointing stage, heading date, and Grouting period (average of two applications per stage).

Testing methods: naked oats was harvested 140 d after sowing, and the following indicators were measured and assayed:

Aboveground fresh weight: Five 1-m^2 naked oats plots were randomly selected for harvesting. The fresh weight of the aboveground biomass was determined, and the yield per hectare was calculated.

Plant height , basal stem diameter, number of spikes, and number of grains per ear: Five naked oats plants were randomly selected in the sample plots to measure plant height using a tape and the basal stem diameter using Vernier caliper.Use counting method to calculate the number of spikes, grains per ear of naked oat.

naked oats seed weight: The fresh weight of the naked oats seeds was measured, and then they were placed in an oven and dried at 60 °C for 12 h. After drying, count 1000 seeds and measure their weight with a analytical balances(analytical balances(FA2204N);JOANLAB company;Zhejiang;China).

Protein: The protein content in naked oats seeds was determined using the Kjeldahl method [20].

Lipid: The lipid content in naked oats seeds was determined via Soxhlet extraction [20].

*crude fiber:*The crude fiber content in naked oats seeds was determined a fixed amount of acid and alkali under specific digestion conditions, with ether degreasing and ethanol removal of alcohol-soluble substances and high temperature scorching. The mass of minerals was deducted and the remaining amount was considered as crude fiber.

starch :starch content in naked oats seeds was determined enzymatic hydrolysis method [20].

*amino acids:*The amino acids content in naked oats seeds was determined using the L-8900 amino acid analyzer manufactured by Hitachi Group, Japan. Due to the differences in acidity, polarity and molecular size of different amino acids, the adsorption capacities of different amino acids to cation exchange resin in different pH environments were also different; the equipment used these characteristics. First, the pH of amino acid samples was adjusted to 2.2, such that all amino acids were adsorbed by the cation exchange resin. As the buffer flowed through the exchange column and the pH of the mobile phase was increased, the positive charge of amino acids was reduced and some amino acids were eluted. The contents of various amino acids in the sample were calculated from the areas of different elution peaks.

Statistical analysis: Graphs were plotted using Origin 2018 SR1 (OriginLab Corporation, Northampton, MA, USA), and statistical analyses were carried out using SPSS *v.*23.0 (SPSS Inc., Chicago, IL, USA). One-way analysis of variance (ANOVA) was performed to test for significant effects of fertilizer application and irrigation quota on the naked oats growth (seed yield, thousand seed weight, number of spikes, number of grains per ear, plant height, and basal stem), and nutrient content (protein, lipid,crude fibre and starch). Two-way ANOVA was performed to test for significance regarding the effects of fertilizer application and irrigation quota on aboveground and naked oats seed biomass, as well as protein and lipid contents. To compare the least significant difference and priming effect at a significance level of 0.05, we performed multiple comparisons using Duncan's test.

RESULTS

Effects of different irrigation quotas and fertilization treatments on naked oats growth and yield:As shown in Figure 3, the growth traits of naked oats responded differently to different irrigation and fertilization conditions, of which fertilization had the largest effect, increasing seed yield by approximately 40% in all irrigation quotas (Figure 3a). Fertilization also improved yield and quality, where the thousand grain weight of fertilized plants was generally higher than that of the unfertilized plants(Figure 3b); the number of ears and the number of grains per ear were also significantly increased because of fertilization(Figure 3c and d). The height of unfertilized plants was slightly higher at the irrigation quota of 750 $m^3 \cdot ha^{-1}$ compared to fertilized ones at that quota, under all other irrigation quotas, the plant height was higher under fertilized conditions; the caudex was less affected by fertilization and showed an insignificant pattern(Figure 3e).The effect of fertilization on the basal stem is not obvious(Figure 3f).

As irrigation quota increased, the seed yield showed a trend of first increasing and then decreasing slightly, and was highest under the irrigation quota of 2250 $m^3 \cdot ha^{-1}$, which resulted in approximately 3250 $kg \cdot ha^{-1}$, a value significantly higher than the respective yields with quotas of 750 m^3 ha^{-1} and 1500 m^3 ha^{-1}(Figure 3a). The

thousand seed weight, number of spikes, number of grains per ear, plant height and basal stem of naked oats basically showed a trend of significant increase when the irrigation quota increased from 750 $m^3 \cdot ha^{-1}$ to 2250 $m^3 \cdot ha^{-1}$. When the irrigation quota continued to increase to 3000 $m^3 \cdot ha^{-1}$, all growth indicators showed a downward trend, among which the basal stem had a significant downward trend.

Effects of different irrigation quotas and fertilization treatments on naked oats quality As can be seen from Table 3, fertilizer treatment increased protein content significantly, from 16.77% (mean value of non-fertilized treatments) to 17.60% (mean value of fertilized treatments). The fat content due to fertilizer treatment was increased by a range of 0.2% to 0.48% when compared with the single non-fertilizer treatment under the same irrigation quota. Fertilization also increased crude fiber content by 0.05% to 0.1% and starch content by 1.17% to 4.71%.

Protein content significantly increased with increasing irrigation quotas, at 1.27% (without fertilizer) and 1.07% (with fertilizer) from 750$m^3 \cdot ha^{-1}$ to 3000$m^3 \cdot ha^{-1}$. Fat content decreased with increasing irrigation quotas, with the largest decrease occurring when the quota increased from 2250 $m^3 \cdot ha^{-1}$. The fat content decreased significantly by 0.4% (no fertilizer) and 0.39% (fertilizer) when irrigation quota increased to 3000$m^3 \cdot ha^{-1}$. Crude fiber level and starch content increased overall with increasing irrigation quota; significant increases were observed for crude fiber when the quota reached 2250$m^3 \cdot ha^{-1}$, and for starch when the quota reached 3000$m^3 \cdot ha^{-1}$.

Table 4 shows the effect of fertilizer application and irrigation quota on amino acid content of naked oats. The contents of 17 kinds of amino acids and total amino acids increased with the increase of irrigation quota.Fertilization promoted the synthesis of most amino acids and total amino acids(except **Cystine**,**Valine,Tyrosine,Ammonia,and Proline**).

Two-way ANOVA of different irrigation quotas and fertilization treatments: Table 5 shows the effect of fertilizer and irrigation quotas alone and fertilizer-irrigation quota interaction on seed yield, thousand grain weight, protein content and starch content of naked oats using two-way ANOVA. Fertilizer and irrigation quotas independently had significant effects ($p < 0.05$) on seed yield, thousand grain weight, protein content and starch content. Fertilizer-irrigation quota interactions only had significant ($p < 0.05$) effects only on thousand grain weight, protein content and starch content, but not on seed yield ($p > 0.05$).

Discussion

Water is a key factor governing crop growth and many previous studies have shown that appropriate increase in irrigation can increase crop yield [21,22]. The present study showed that when no fertilizer was applied to naked oats and irrigation quota increased from 750$m^3 \cdot ha^{-}1$ to 1500 $m^3 \cdot ha^{-1}$, yield increased significantly by 21%. When the irrigation quota continued to increase to 2250 $m^3 \cdot ha^{-1}$, yield increased by 19.4%; however, when irrigation quota increased to 3000 $m^3 \cdot ha^{-1}$, yield increased by only 1.3%. The increase in yield with increasing irrigation quota showed a slowing trend, which is consistent with the findings of Batool H and Wang T et al. [23,24,25]. The trend of ear number, ear grain number and thousand grain weight with irrigation quota was almost the same as the trend of yield, and all showed an initial increase. When the irrigation quota reached 2250 $m^3 \cdot ha^{-1}$ and continued to increase, ear number, ear grain number and thousand grain weight increased minimally or slightly decreased, indicating that an increase in irrigation does not increase naked oat production and therefore would be an inefficient use of water.

Changes in moisture not only affect crop yield, but also change the quality of crops [26]. Peng-li Yue studied the effect of high temperature drought stress on the starch content in wheat kernels, and the results showed that drought and high temperature greatly reduced starch synthesis, which affected yield [27]. This is consistent with the results of the present study, which found that increased irrigation increased starch content of naked oats. The crude protein content of naked oats was found to increase and then decrease with increasing irrigation quotas, peaking at an irrigation quota of 150 mm in the study by Wu (2010) [28]. In this study, the protein content of naked oats increased with increasing irrigation quota, which was different from Wu (2010) because the maximum irrigation quota in this study was 3000 $m^3 \cdot ha^{-1}$, which is less than the irrigation quota of 150mm (equivalent to 3373.3 $m^3 \cdot ha^{-1}$). Therefore, only a trend of increasing protein content with increasing irrigation was observed in this study.

Developed countries attach great importance to the use of organic fertilizers in agricultural production. Manure helps to supplement soil nutrients and reduce the use of chemical fertilizers [29,30]. In this experiment, combined with the staggered planting environment of farming and grazing in northern China, cow and sheep manure was selected as the base fertilizer in the four treatments.A large number of studies have shown that use of organic fertilizer can improve the physical and chemical properties of soil, and increase soil biological richness, enzyme activity, and nutrients, thus providing better conditions for growth of plant roots [31,32,33,34]. Numerous studies have been conducted regarding the effects of organic fertilizer application on crop yield and quality, and the vast majority has demonstrated a positive correlation between the two [35,36]. Cen et al. (2006) used organic fertilizer instead of chemical fertilizer in cassava planting, and the results of that study showed that the use of organic fertilizer promoted cassava plant height, stem diameter, and leaf area index [37]. Ertilization was based on local soil nutrients and fertilizer application was adjusted to arrive at the optimum application method [38]. The original soil at the test site was low in available nitrogen and potassium and particularly low in available phosphorus. Therefore, this experiment was designed with two fertilizer treatments. Tobiasz-Salach (2016) found in a foliar fertilization experiment on naked oats that fertilizer application increased the number of ears, ear grain size, thousand grain weight and fat content [39]. The study by Panasiewicz (2017) also showed that fertilizer application increased naked oat yield which is consistent with this work [40]. The results of the present study showed that the average seed yield of naked oats without fertilizer application was 2088 $kg \cdot ha^{-1}$, and the average seed yield under fertilizer application was 2976 $kg \cdot ha^{-1}$, an increase of up to 42.5%, indicating that fertilizer application can greatly increase the yield of naked oats.

Nitrogen, phosphorus and potassium in fertilizers are the major components of plant organic matter such as plant proteins, vitamins and enzymes and studies have found that fertilizer application increases protein content and starch accumulation in crops. Similarly, nitrogen fertilization increases amino acid content in naked oats. The results of this study showed that the amount of protein, fat, crude fiber, starch content and amino acids increased to varying degrees due to fertilizer application at the same irrigation quota, indicating that fertilizer application and increased irrigation promoted nutrient synthesis.

Conclusions

This study examined the effects of different irrigation quotas and fertilizer treatments on naked oat cultivation in agriculture-pastoral zone in semi-arid areas. Naked oat yield increased with increasing irrigation quotas, but the same amount of water has less and less effect on the yield of oats. Moreover, increased irrigation improved the

quality of naked oats. Fertilizer application increased yield and quality of naked oats. The findings of the experiment undertaken provide a theoretical basis for the cultivation of naked oats in agriculture-pastoral zone in semi-arid areas in terms of irrigation and fertilization. In addition, regarding the further improvement of naked oats yield in agriculture-pastoral zone in semi-arid areas, intercropping with other crops, improvement of seed quality, optimization of irrigation methods, and nutrient and water requirements of naked oats at various growth stages warrant further investigation.

Declarations

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Authors' Contribution Statement

BC and JW designed the study; BC and DHY performed the experiments; BC and ZHM analyzed the data and wrote the manuscript; JW and LH provided important and valuable suggestions for designing the study and manuscript writing. All authors commented on previous versions of the manuscript and have read and approved the final manuscript.

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Ethics declarations

The plant collection and use was in accordance with all the relevant guidelines.

Competing interests

The authors declare that there is no conflict of interest.

Data availability statement

All relevant data are within the paper.

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Tables

Table 1. Soil physicochemical properties.

	pH	SOM (g·kg^{-1})	SAP (mg·kg^{-1})	SAK (mg·kg^{-1})	SAN (mg·kg^{-1})	FWH (%)	SBD (g·cm^{-3})
0–15 cm	8.16	14.98	0.94	153.5	58.92	16.02	1.64
15–30 cm	8.65	11.88	0.44	89	34.082	19.8	1.42

SOM, soil organic matter; SAP, soil available phosphorous; SAK, soil available kalium; SAN, soil alkali nitrogen; FWH, field water holding capacity; SBD, soil bulk density.

Table 2. Study design for naked oats growth treatments.

Treatment	Number	Irrigation quota ($m^3 \cdot ha^{-1}$)	Number of irrigations (treatments)	Irrigation quota ($m^3 \cdot ha^{-1}$)
Unfertilized	Y1	75	10	750
	Y2	150	10	1500
	Y3	225	10	2250
	Y4	300	10	3000
Fertilized	AY1	75	10	750
	AY2	150	10	1500
	AY3	225	10	2250
	AY4	300	10	3000

Table 3. Effects of different irrigation quotas and fertilization treatments on naked oats quality.

Treatment	Protein (%)	Lipid (%)	crude fiber□%□	starch□%□
Yl	16.23±0.08 a	8.51±0.06 c	1.46±0.06a	47.47±0.51a
Y2	16.69±0.14 b	8.49±0.04 c	1.51±0.08a	47.56±0.49a
Y3	16.73±0.17 b	8.44±0.03 bc	1.66±0.06bc	47.78±0.19a
Y4	17.50±0.10 d	8.04±0.06 a	1.72±0.08cd	49.32±0.67b
AYl	17.05±0.10 c	8.99±0.07 d	1.51±0.18a	48.64±0.57ab
AY2	17.39±0.25 d	8.90±0.12 d	1.56±0.09ab	49.43±0.84b
AY3	17.91±0.28 e	8.63±0.29 c	1.76±0.04cd	49.75±1.34b
AY4	18.12±0.1 e	8.24±0.13 ab	1.82±0.08d	54.03±0.68c

Note: (1)Different lower-case letters within a column indicate significant differences ($p < 0.05$) in the nutritional indicator of naked oats under different treatments.(2)Treatment abbreviations are detailed in Table 3.

Table 4. Effects of different irrigation quotas and fertilization treatments on naked oats amino acid.

amino acid	Y1	Y2	Y3	Y4	AY1	AY2	AY3	AY4
	content （%）	content （%）	content （%）	content （%）	content （%）	content （%）	content （%）	content （%）
Aspartic acid	1.163	1.161	1.225	1.286	1.169	1.185	1.239	1.300
Threonine	0.482	0.491	0.515	0.538	0.485	0.499	0.514	0.538
Serine	0.653	0.666	0.7	0.727	0.653	0.687	0.701	0.733
Glutamate	2.925	2.932	3.13	3.282	2.976	3.060	3.149	3.279
Glycine	0.680	0.700	0.725	0.752	0.679	0.701	0.719	0.753
Alanine	0.677	0.689	0.714	0.749	0.678	0.688	0.717	0.750
Cystine	0.393	0.409	0.424	0.431	0.372	0.372	0.405	0.423
Valine	0.780	0.789	0.821	0.857	0.765	0.785	0.822	0.854
Methionine	0.161	0.175	0.121	0.183	0.176	0.196	0.215	0.216
Isoleucine	0.526	0.529	0.549	0.595	0.524	0.555	0.564	0.596
Leucine	1.080	1.095	1.151	1.225	1.086	1.131	1.154	1.228
Tyrosine	0.487	0.505	0.499	0.529	0.469	0.500	0.498	0.523
Phenylalanine	0.762	0.766	0.802	0.846	0.779	0.786	0.809	0.842
Lysine	0.563	0.579	0.589	0.623	0.567	0.581	0.595	0.623
Ammonia	0.327	0.323	0.350	0.370	0.324	0.345	0.346	0.362
Histidine	0.316	0.319	0.341	0.354	0.320	0.330	0.341	0.358
Arginine	0.980	0.991	1.039	1.104	0.989	1.041	1.068	1.119
Proline	0.720	0.738	0.767	0.798	0.710	0.735	0.756	0.792
Total	13.148	13.554	14.112	14.879	13.357	13.834	14.266	14.926

Note: Treatment abbreviations are detailed in Table 4.

Table 5. Results of a two-way ANOVA on the effects of fertilization and irrigation quotas on naked oats seed thousand seed weight, seed yield, as well as protein and Starch content.

	F value				P value			
	Seed yield	Thousand seed weight	Protein	Starch	Seed yield	Thousand seed weight	Protein	Starch
Fertilization	246.745	144.66	148.88	66.39	0*	0*	0*	0*
Irrigation quota	35.797	19.4	52.24	30.48	0*	0*	0.80*	0.13*
Fertilization×Irrigation quota	0.278	9.54	3.41	6.87	0.84	0.001*	0.043*	0.003*

Note: Asterisks in the table indicate a significant difference ($p < 0.05$).

Figures

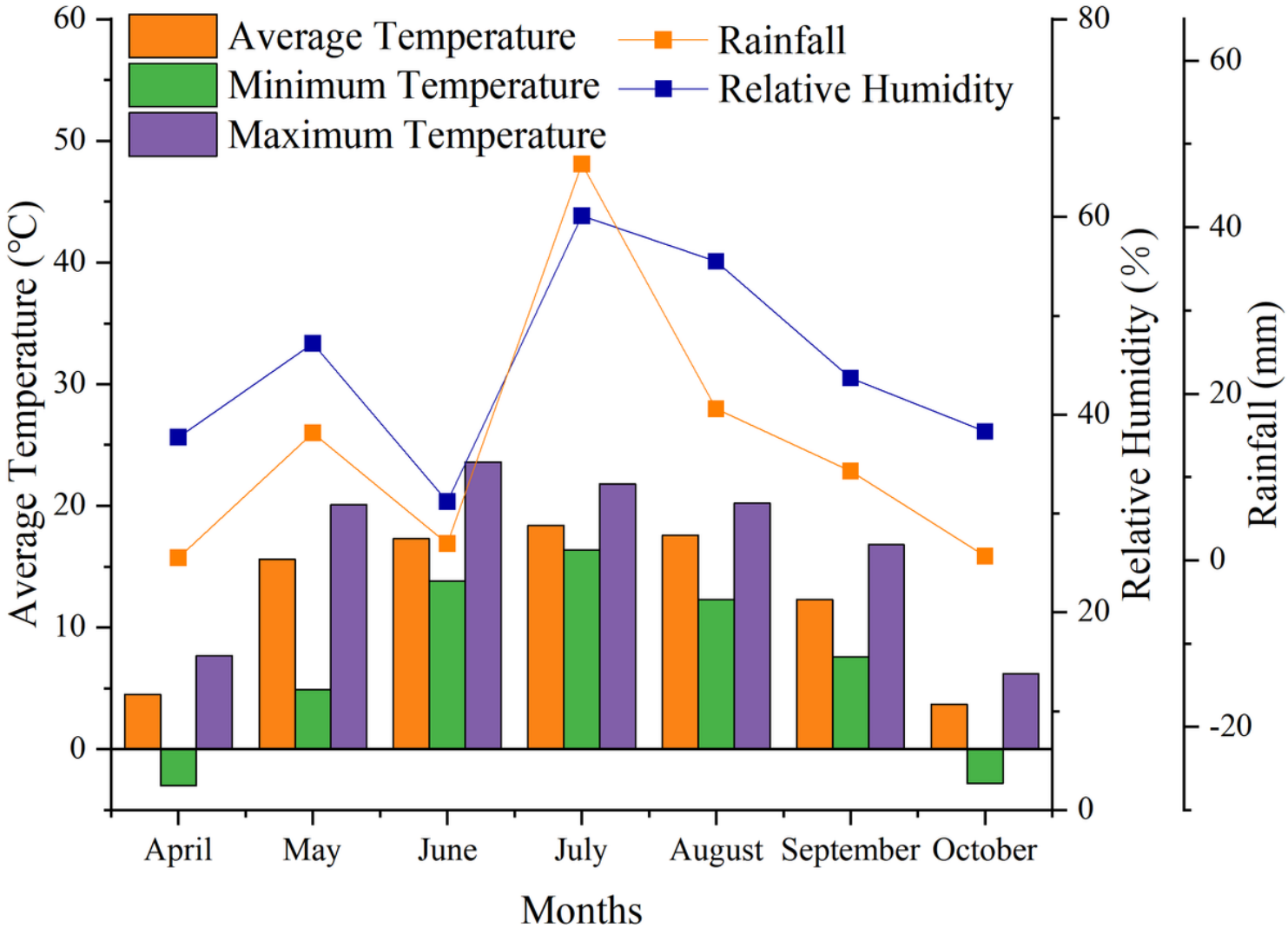


Figure 1

Climatic data of test site from April to October 2020

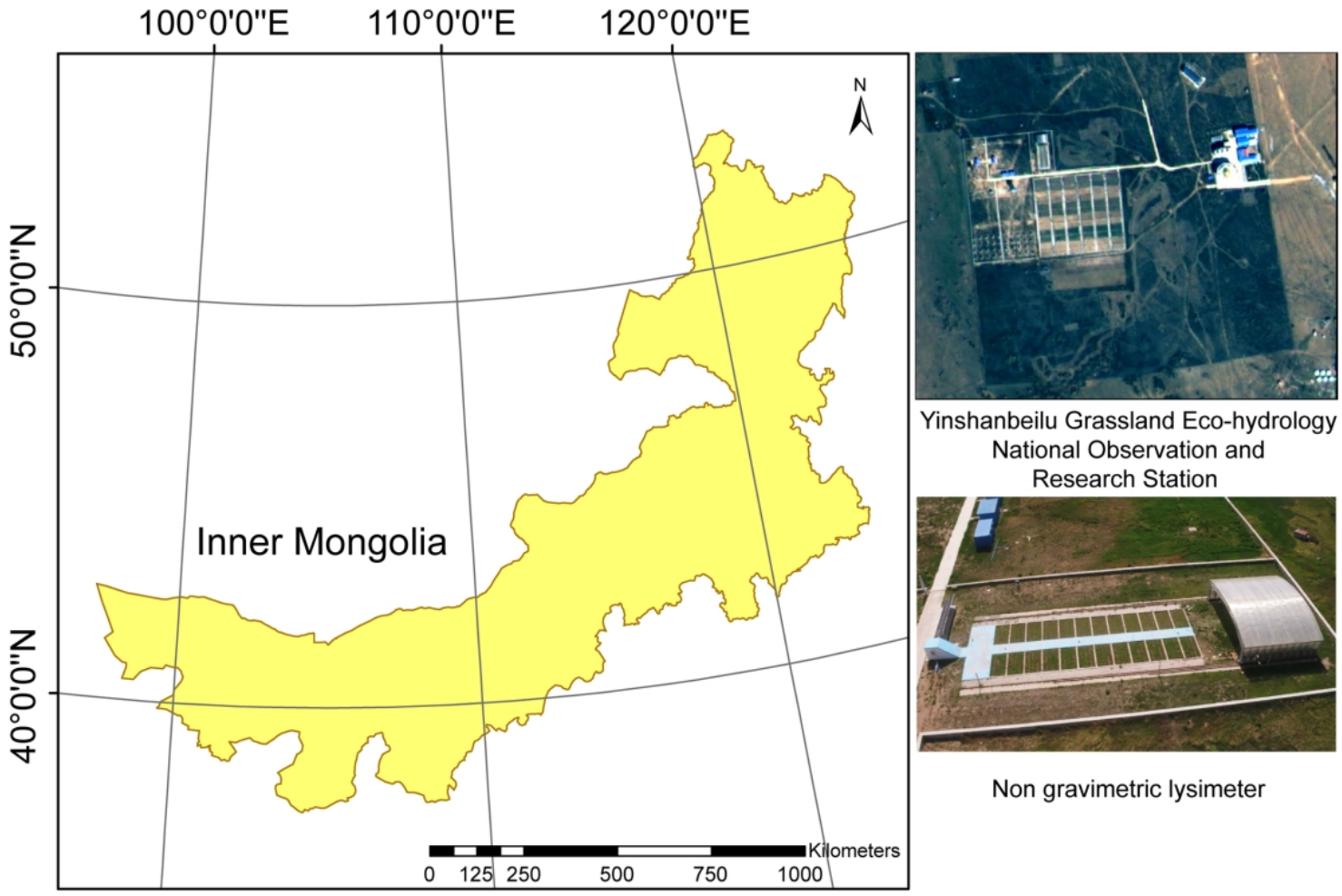


Figure 2

Geographical location map of the project area

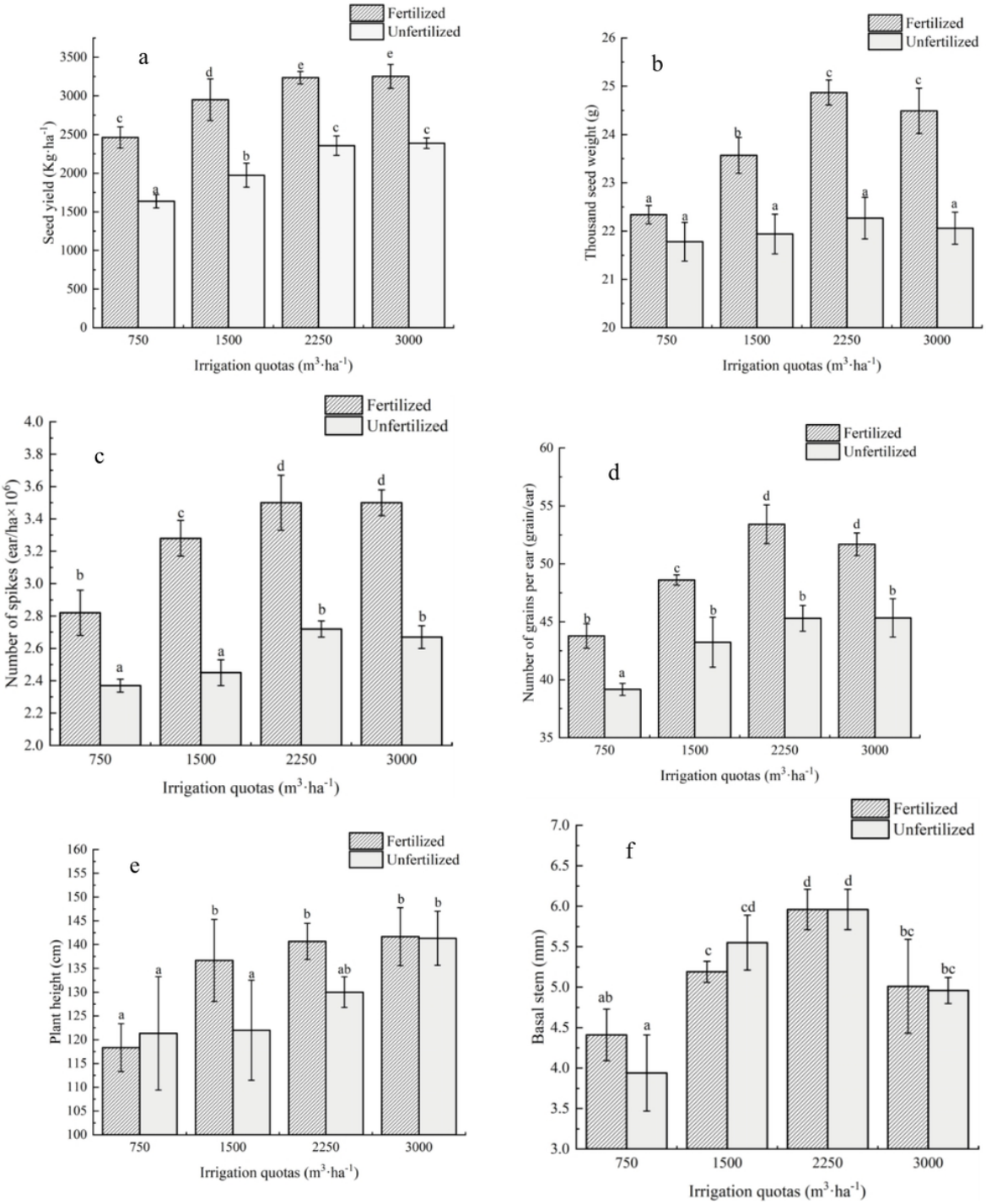


Figure 3

Effects of different irrigation quotas and fertilization treatments on naked oats growth and yield. (a) seed yield, (b) thousand seed weight, (c) number of spikes, (d) number of grains per ear,(e)plant height,and(f)basal stem. Different uppercase letters above the bars indicate significant differences ($p < 0.05$) in naked oats growth between different irrigation quotas without fertilizer application, and different lower-case letters above the bars indicate significant differences ($p < 0.05$) in naked oats growth between different irrigation quotas with fertilizer application.