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Effects of Water and Nitrogen Regulation on Dry Matter Accumulation, Yield and Water Use of Sweet Sorghum

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Abstract

This experiment is to find a water-fertilizer coupling model for water-saving and fertilizer-saving cultivation of sweet sorghum (Nengsi No.2) in the semi-humid area of Heilonggang, using 2 factors (4 irrigation levels and 3 fertilization levels) for field experiments. The result shows: mild water deficit and appropriate increase of nitrogen fertilizer can accelerate the absorption of water and nitrogen by promoting root growth, facilitate the distribution of photosynthetic products to the stems, increase the proportion of stem dry matter. Under W3N2 treatment, larger fresh weight yield (151251.9kg/hm2) and dry weight yield (45284kg/hm2) were obtained. irrigation, nitrogen application and their interaction have extremely significant effects on dry matter accumulation and distribution and yield, irrigation is the main factor and nitrogen application is a secondary factor; the water use efficiency (10.44kg/m3) of W3N2 treatment is the maximum value of each treatment, irrigation, nitrogen application and their interaction have a significant impact on water use efficiency, irrigation is the main factor affecting water use efficiency and nitrogen application is a secondary factor. In summary, the optimal water and nitrogen treatment under the experimental conditions was W3N2 treatment. Compared with the control treatment W4N2 treatment, the fresh weight yield and dry matter yield increased by 0.26% and 1.16% respectively, saving 469.5 m3 of irrigation water per hectare which can achieve energy saving, the purpose of water reduction of nitrogen.

Keywords

Sweet sorghum; Water and nitrogen regulation; Dry matter; Yield; Water use efficiency.

1. INTRODUCTION

The animal husbandry industry in Hebei Province has been developing rapidly since the 1980s, but the forage grass industry is the most important material and basic industry for the animal husbandry industry. It is still in its infancy. There is still a certain distance from the formation of a complete industrial system. The technological level and production methods of the grass industry are relatively backward, and the huge demand of modern animal husbandry is obviously difficult to meet. With the development of animal husbandry and the adjustment of agricultural structure, high-quality forage grass has increasingly become a key factor restricting the development of high-quality and high-efficiency animal husbandry in Hebei Province. To develop high-quality and efficient animal husbandry, it is necessary to establish an efficient forage industry system. Sweet sorghum (Sorghum bicolor (L.) Moench) is a variant of common grain sorghum [1]. It has large biological yield, strong adaptability, high nutritional value, and good palatability. It can be used for both grain and feed, and it can achieve no competition with grain. Land, especially in drought years, the economic benefits obtained are particularly significant. Groundwater over-extraction in Heilonggang area is serious, lack of irrigation water

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resources and soil and fertilizer conditions restrict the high yield of crops and the sustainable development of agriculture [2]. Sweet sorghum has excellent drought resistance and stress resistance. It is a traditional dominant crop in Heilonggang area. It is of practical significance to conduct in-depth theoretical research in this area.

Appropriate water and fertilizer irrigation mode is an important basis for high quality and high yield of sweet sorghum [3, 4]. Coordinating the relationship between water and fertilizer is beneficial to promote crop growth, improve crop growth environment, and increase crop yield and water and fertilizer use efficiency [5-7]. Studies have found that water deficit will cause the stomata of leaves to close and the photosynthesis rate to decrease, thereby reducing the water conduction in the plant, causing its growth to be inhibited [8, 9]. Sorghum will have obvious compensation benefits after water deficit and rewatering at different growth stages, and the purpose of saving water and increasing production can be achieved by changing its own photosynthetic rate [3]. Studies have found that applying appropriate amounts of nitrogen fertilizer can effectively ensure the nutrient requirements of crops, thereby significantly increasing crop yield and improving water use efficiency [10-12], but too much nitrogen fertilizer can easily cause plant lodging and reduce yield [13]. At present, there are few systematic research results on the effects of irrigation and fertilization on the growth, yield, and water and fertilizer use of sweet sorghum. This article uses field experiments to study the effects of irrigation levels and different nitrogen application rates on the growth and dry matter accumulation of sweet sorghum plants in the semi-humid area of Heilonggang. To explore the optimal combination of water and fertilizer for water-saving and increasing production of sweet sorghum in consideration of the effects of distribution, yield and water and fertilizer utilization, and to provide sufficient scientific basis for optimizing the irrigation mode of sweet sorghum in this area.

2. MATERIALS AND METHODS

2.1. Overview of the Test Area

The experiment was carried out at the Comprehensive Experimental Station of Hebei Agricultural University, July County, Xingtai City, Hebei Province from April to October 2019 (115°13′24″E, 37°34′51″N, altitude 28.50m). The test area belongs to a typical temperate monsoon climate, a semi-humid area, with an average annual temperature of 13.7°C, a frost-free period of 202 days, an average annual sunshine duration of 2767.4h, an average annual evaporation of 2200~3000mm, an average annual precipitation of about 509mm, and most of the rainfall is concentrated From July to August, the groundwater depth is about 40m. The basic physical and chemical properties of 0-20cm test soil were determined as follows: organic matter content 8.97g/kg, total nitrogen 0.54g/kg, total phosphorus 0.89g/kg, total potassium 22.69g/kg, alkali hydrolysable nitrogen 33.17mg/kg, available phosphorus 1.82mg/kg, quick-acting potassium 169.32mg/kg. The average soil bulk density is 1.396 g/cm3, and the field water holding rate is 34.48% (v/v). The test soil was brown loam, and the previous crop was silage corn.

2.2. Test Design

The experiment was sown on April 27, and the entire growth period was 150 days, which was divided into 5 growth stages as shown in Table 1. The experiment set two factors: irrigation level and nitrogen application level. The irrigation water limit for the whole growth period of sweet sorghum is set at 60%±5% of the field water holding rate, and the upper irrigation limit is 90% of the field water holding rate. Take 3 fully irrigated plots every 3 days and repeat the 0-100cm soil sample for drying. Measure the change of soil water content. When the water content of the fully irrigated plot reaches the lower limit, all treatments are irrigated at the same

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time, and the fully irrigated treatment is irrigated to the upper limit of irrigation, and the full irrigation quota is I0. Irrigation quotas are set at 4 levels: full irrigation W4 (100% I0), mild water deficit irrigation W3 (75% I0), moderate water deficit irrigation W2 (50% I0), severe water deficit irrigation (25% I0). The depth of the planned moist layer for each growth period is taken: 40 cm at the seedling stage, 70 cm at the jointing stage, 70 cm at the heading stage, 80 cm at the milk maturity stage, and 80 cm at the mature stage. Three levels of nitrogen application rate are set: high nitrogen level N3 (N400kg/hm2), medium nitrogen level N2 (N300kg/hm2) and low nitrogen level N1 (N200kg/hm2), where N2 is the recommended nitrogen application rate, denoted as RN. Before sowing, apply compound fertilizer (N:P:K=15-15-15) 333kg/hm2, phosphate fertilizer (superphosphate, P2O512%) 417 kg/hm2, and potassium fertilizer (potassium sulfate, K2O52%) 96kg/hm2 as apply the base fertilizer, perform rotary tillage and leveling. The remaining nitrogen fertilizer of each treatment was applied with 60% and 40% topdressing urea (N 46.2%) at the jointing stage of sweet sorghum (June 20) and the bell mouth stage (July 4). For maximum utilization, the irrigation amount and nitrogen application amount during each growth period of sweet sorghum are shown in Table 2. The experiment is a completely random combination design, a total of 12 treatments, the control treatment CK is W4N2, each treatment is repeated 3 times, a total of 36 cells. The field management measures are the same as the farming habits of local farmers.

Table 1. Division of sweet sorghum growth period

SEEDLING STAGE	JOINTING PERIOD	HEADING DATE	MILK MATURITY	MATURITY
APRIL 27-JUNE 5	JUNE 6-JULY 25	JULY 26-AUGUST 9	AUGUST 10-AUGUST 30	AUGUST 31-SEPTEMBER 19

Table 2. Irrigation and fertilization schemes for each treatment

W	N	IRRIGATION LEVEL	NITROGEN APPLICATION LEVEL	IRRIGATION VOLUME (MM)	N DOSAGE (KG/HM2)
	N1	**25%I0**	**2/3RN**	49.6	200
W1	**N2**	**25%I0**	**RN**	49.6	300
	N3	**25%I0**	**4/3RN**	49.6	400
	N1	**50%I0**	**2/3RN**	93.8	200
W2	**N2**	**50%I0**	**RN**	93.8	300
	N3	**50%I0**	**4/3RN**	93.8	400
	N1	**75%I0**	**2/3RN**	140.6	200
W3	**N2**	**75%I0**	**RN**	140.6	300
	N3	**75%I0**	**4/3RN**	140.6	400
	N1	**100%I0**	**2/3RN**	187.5	200
W4	**N2**	**100%I0**	**RN**	187.5	300
	N3	**100%I0**	**4/3RN**	187.5	400

2.3. Measurement Items and Methods

2.3.1 Determination of soil moisture content

At the end of different growth stages of sweet sorghum, 5 plants in each plot of each treatment were selected to measure the dry matter mass of stems, leaves, and ears. The dry matter mass ratio of each part of the organ was the total dry matter mass ratio of the organs in the current period. First, put the different organs in an oven at 105°C for 0.5h, and then dry them to constant weight at 75°C to determine the dry matter quality. The dry matter mass of each organ per hectare is the average dry matter per treatment multiplied by the planting density per hectare.

The mass of dry matter harvested at maturity is converted into dry weight yield Y.

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2.3.2 Crop water consumption

The drying method was used to determine the soil moisture content in different periods. In the 0-100 cm soil layer, every 10 cm is one layer, and the volumetric moisture content is measured by layer. The water consumption is calculated using the water balance equation [15], namely:

$$ET = I + \triangle W + P_{eff} + K - D - R$$

In the formula: ET is the water consumption in the time period (mm); I is the irrigation water volume in the time period (mm); △W is the change in the soil water storage at 1 m depth in the time period (mm); Peff is the effective rainfall in the time period (mm); K is the amount of groundwater replenishment in the period (mm); D is the leakage in the period (mm); R is the runoff (mm) in the period. Due to less rainfall, better soil water holding capacity in the root zone and greater soil depth, no runoff occurred in the test plot, so R was ignored. At the same time, the average buried depth of groundwater in the test area is relatively large (greater than 40 m) and the irrigation quota is small, so K and D are not considered.

2.3.3 Water use efficiency

The calculation formula for water use efficiency (WUE) is as follows:

$$WUE = \frac{Y}{ET}$$

In the formula, WUE is the water use efficiency, kg/m3; Y is the dry matter yield of sweet sorghum, kg/hm2, ET is the total water consumption during the growth period, m3.

2.4 Data analysis

Microsoft Excel 2007 (Microsoft Corp. WA, USA) software was used for statistical analysis and graphing of data, SPSS18.0 (IBM Corp, NY, USA) software was used for analysis of variance (ANOVA), and multiple comparison analysis was performed by Duncan method (P< 0.05).

3. RESULTS AND ANALYSIS

3.1. Effect of Water and Nitrogen Regulation on Dry Matter Accumulation of Sweet Sorghum

It can be seen from Figure 1 that with the growth of sweet sorghum, the change trend of dry matter accumulation of sweet sorghum under different water and nitrogen treatments is as follows: dry matter accumulation is less in the seedling stage, and the nutrient growth is active as it enters the jointing stage. The accumulation rate of dry matter increased significantly, and the above ground dry matter accumulation rate of each treatment reached the peak at the heading stage, then the accumulation rate slowed down, and the aboveground dry matter accumulation of each treatment of sweet sorghum reached the maximum at the maturity stage. In the seedling stage, the nitrogen application rate of all treatments was the same. At this time, the difference in dry matter accumulation between full irrigation (W4) and mild deficit irrigation (W3) was not significant (P>0.05), and moderate deficit irrigation (W2) and Severe deficit irrigation (W1) has no significant difference (P>0.05); In the jointing stage, the differences between the treatments were significant (P<0.05). The dry matter accumulation of W4N3 treatment was the largest (25662.7kg·hm-2). Under the same nitrogen application rate, the dry matter accumulation of W4 treatment was higher than that of W3, W2 and W1 are 16.53%, 66.39% and 126.44% higher. Under the same irrigation volume, the dry matter accumulation of N2 treatment is 6.92% and 20.70% higher than N3 and N1 respectively; during the heading stage, vegetative growth and reproductive growth go hand in hand. In the early stage, the growth of stalks and leaves is dominant, and the ears of sweet sorghum also grow significantly in the later stage. With the decrease of irrigation, the dry matter accumulation rate of sweet sorghum increases significantly, which is similar to the jointing stage. The dry matter

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accumulation rate of W1 treatment is 18.91%, 30.69% and 70.03% higher than that of W2, W3 and W4. The dry matter accumulation of sweet sorghum at different nitrogen levels under the same irrigation level is as follows: N2>N3>N1, where N2 treatment is 5.41% and 17.95% higher than N3 and N1; after the heading stage, the aboveground dry matter accumulation rate of sweet sorghum decreased significantly, and the aboveground dry matter accumulation rate of each treatment at the heading-milk stage was 108.39 ~213.95kg/d/hm2; The dry matter accumulation rates of the shoots of W1, W2, W3 and W4 in the milk-maturing-maturing period were 107.95, 119.86, 176.49 and 137.44 kg/d/hm2, among them the mild water deficit treatment (W3) increased by 14.48% compared with the heading-milk-maturing stage, and the positive growth rate could be maintained during the milk-maturing stage, this shows that the dry matter accumulation rate of sweet sorghum after the heading stage decreases firstly and then increases with the increase of irrigation amount. Appropriate water deficit can slow down the decline of dry matter accumulation rate; the treatment with the largest final accumulation of dry matter in the shoots of sweet sorghum at maturity is W3N2 treatment, it shows that mild water deficit is conducive to the accumulation of dry matter, too low irrigation water will affect the growth of sweet sorghum, Under the same irrigation conditions, the final accumulation of dry matter on the ground of sweet sorghum at maturity stage is: N2>N3>N1, it shows that reasonable increase of nitrogen fertilizer can increase the accumulation of dry matter of sweet sorghum, but excessive nitrogen fertilizer may inhibit the growth of sweet sorghum, which is not conducive to the accumulation of dry matter.

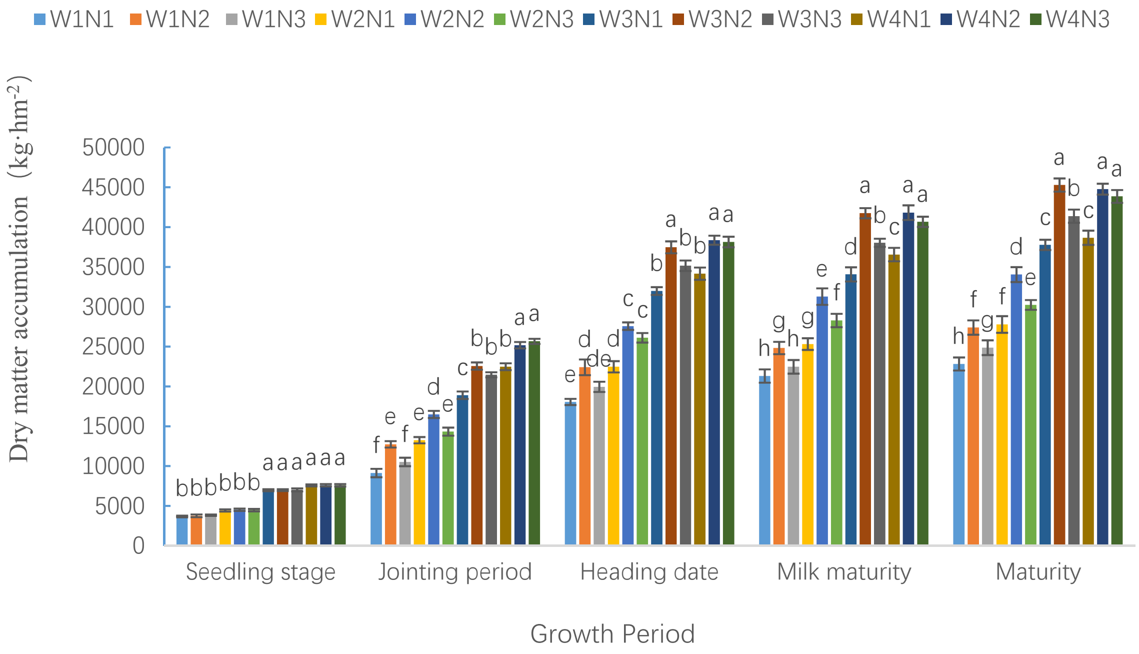

Figure 1. Dry matter accumulation of sweet sorghum under the regulation of water and nitrogen

It can be seen from Table 3 that there is an interaction between the two factors of irrigation and nitrogen application on the dry matter accumulation during the growth period of sweet sorghum, and the effects of irrigation, nitrogen application and the interaction between the two have reached a very significant level. The main factor of dry matter accumulation in sweet sorghum.

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Table 3. The results of two-factor analysis of variance of the aboveground dry matter accumulation during the growth period of sweet sorghum

index	F value	Growth Period				
		Seedling stage	Jointing period	Heading date	Milk maturity	Maturity
Dry matter accumulation	W	223.23**	342.61**	283.88**	339.28**	315.29**
	N	0.47ns	150.78**	92.47**	101.09**	108.55**
	W×N	0.14ns	15.79**	12.65**	13.51**	13.38**

Note: Different lowercase letters indicate significant differences at P=0.05 between different treatments. * Indicates a significant difference (P<0.05); ** indicates a very significant difference (P<0.01); ns indicates no significant difference (P>0.05).

3.2. Effect of Water and Nitrogen Regulation on the Yield and Components of Sweet Sorghum

It can be seen from Table 4 that different water and nitrogen control treatments have significant effects on the fresh weight yield of sweet sorghum shoots, the fresh weight yield of stalks, and the dry weight yields of shoots, the three yields are basically the same according to different water and fertilizer treatments. The total fresh weight yield, stalk fresh weight yield, and dry weight yield of W3N2 treatments are the largest among all treatments, the above-ground fresh weight yield of W3N2 treatment was 0.26% and 2.34% higher than that of W4N2 and W4N3 treatments, respectively, the stalk fresh weight yield was 1.1% and 3.2% higher respectively, the dry weight yield of the above-ground part was 1.16% and 3.26% higher respectively, the differences were not significant (P<0.05), except for W4N2 and W4N3 treatments, the yield of W3N2 treatment was significantly higher than that of other treatments. With the increase of irrigation amount, the aboveground fresh weight yield, stalk fresh weight yield and aboveground dry weight yield of sweet sorghum showed an upward trend, there is no significant difference between the treatment with mild deficit irrigation (W3) and the treatment with full irrigation (W4). Among them, the above-ground fresh weight yield of W4 treatment increased by 3.21%, 41.19% and 76.34%, respectively, compared with W3, W2 and W1, the stalk fresh weight yield increased by 2.59%, 40.61% and 74.52%, and the aboveground dry weight yield increased by 2.29%, respectively. 38.26% and 69.54%, which indicate that the increase of water can increase the yield by promoting the growth of sweet sorghum, but too much water is not conducive to water saving and yield increase of sweet sorghum. With the increase of nitrogen application rate, the aboveground fresh weight yield, stalk fresh weight yield, and aboveground dry weight yield of sweet sorghum all increased first and then decreased. The yield of sweet sorghum was significantly different at different nitrogen application levels, among which N2 The above-ground fresh weight yield of the treatment was increased by 19.22% and 7.91%, respectively, compared with N1 and N3, the stalk fresh weight yield was increased by 20.49% and 7.85%, and the above-ground dry weight yield was increased by 19.24% and 7.95%, respectively, indicating that increased nitrogen fertilizer application can be effective Increase the yield of sweet sorghum, but too much nitrogen fertilizer may cause a decrease in soil permeability, resulting in difficulty in water absorption by the roots of sweet sorghum and a decrease in yield.

Irrigation and nitrogen application have an interactive effect on the above-ground fresh weight yield, stalk fresh weight yield and above-ground dry weight yield of sweet sorghum, and the effects of irrigation, nitrogen application and the interaction of the two have reached extremely significant levels (P <0.05). Irrigation amount is the main factor affecting the above-ground fresh weight yield, stalk fresh weight yield and above-ground dry weight yield of sweet sorghum. Nitrogen application is a secondary factor.

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Table 4. Yield and yield composition of sweet sorghum under the regulation of water and nitrogen

Treatment		Aboveground fresh weight yield ($kg·hm^{-2}$)	Stalk fresh weight yield ($kg·hm^{-2}$)	Aboveground dry weight yield ($kg·hm^{-2}$)
W1N1		73949.1±2381.6h	58257.1±698.1h	22823.8±342h
W1N2		88744.9±2409.37f	70913.2±1127.3f	27390.4±576.6f
W1N3		80555.8±1987.3g	64461.9±710.6g	24862.9±484.2g
W2N1		91680.9±2164.1f	71226.2±826.6f	27782.1±321.9f
W2N2		112345.2±2736.9d	89505.6±1039.6d	34044±585.5d
W2N3		99771.5±2269.6e	79601.1±910.4e	30233.8±456e
W3N1		126152.1±2533.8c	99382.7±868.9c	37770.1±384.6c
W3N2		151251.9±2500.2a	120156.2±1137.8a	45285±342.5a
W3N3		138189.2±1927.4b	109865.4±580.5b	41374±354.2b
W4N1		130293±2691.3c	102644.8±786.3c	38662.6±355.1c
W4N2		150858.1±2947.8a	118846±1369.7a	44765±264.6a
W4N3		147795.4±2375.9a	116433.2±1270.5a	43856.2±342.1a
Irrigation treatment	W1	81083.3±3137.8c	64544.1±1829.1c	25025.7±781.3c
	W2	101265.9±3740.2b	80111±2539.2b	30686.6±1047.8b
	W3	138531.1±4311.2a	109801.4±2569.1a	41476.4±1477.4a
	W4	142982.1±4914.7a	112641.3±3266.7a	42427.9±1890.1a
Nitrogen treatment	N1	105518.8±4408.1c	82877.7±3790.4c	31759.7±1807.2c
	N2	125800±4896.4a	99855.3±5134.6a	37871.1±3115.6a
	N3	116578±5327.9b	92590.4±4517.7b	35081.7±2230.1b
F value	W	347.63**	340.11**	315.29**
	N	174.31**	194.36**	108.55**
	W×N	16.44**	17.51**	13.38**

Note: a, b, c indicate significant differences at P=0.05 level, * indicates significant difference (P<0.05), ** indicates extremely significant difference (P<0.01), ns indicates not significant difference. The data represents the mean ± standard deviation under the same treatment. Different lowercase letters in the same column of data indicate significant differences; if there are any identical lowercase letters, it indicates that the differences are not significant.

3.3. Effect of Water and Fertilizer Regulation on Water Use Efficiency of Sweet Sorghum

Figure 2 shows the water use efficiency of sweet sorghum under different water and nitrogen treatments. The maximum water use efficiency (10.44kg/m3) was obtained under W3N2 treatment, and the minimum water use efficiency (5.84 kg/m3) was obtained under W1N1 treatment. With the increase of irrigation amount, the water use efficiency of sweet sorghum increased first and then decreased, reaching the maximum under W3 irrigation level. Among them, W3 treatment increased by 4.53%, 27.79% and 45.18% compared with W4, W2 and W1 treatments, respectively, there is no significant difference between W3 and W4 treatments (P>0.05). With the increase of nitrogen application rate, except for full irrigation (W4) treatment, the water use efficiency of sweet sorghum also showed a trend of first increasing and then decreasing, reaching the maximum under N2 nitrogen application rate, and N2 treatment was better than N1 and N3 treatments. Increases by 23.42% and 14.46%; water use efficiency N3 under full irrigation, compared with N2 and N1 treatments, increased by 3.4% and 16.76%. The difference between N3 and N2 treatments was not significant (P>0.05).

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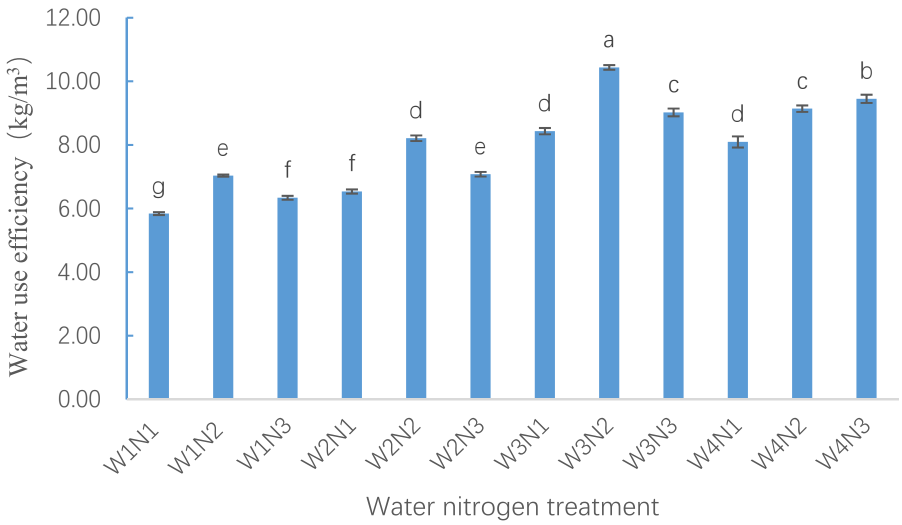

Figure 2. Water use efficiency of sweet sorghum under different water and nitrogen treatments

It can be seen from Table 6 that there is an interaction between the two factors of irrigation and nitrogen application on the water use efficiency of sweet sorghum, and the effects of irrigation, nitrogen application and the interaction of the two have reached extremely significant levels. The amount of irrigation affects the water use efficiency of sweet sorghum. The main factor of efficiency, nitrogen application rate is a secondary factor.

Table 5. Two-factor analysis of variance for water use efficiency of sweet sorghum

Treatment		Water use efficiency (kg/m3)
F value	W	317.84**
	N	77.41**
	W×N	8.73**

Note: Different lowercase letters indicate significant differences at P=0.05 between different treatments. * Indicates a significant difference (P<0.05); ** indicates a very significant difference (P<0.01); ns indicates no significant difference (P>0.05).

4. DISCUSS

Adequate water and nitrogen supply is the basis for ensuring high yield of sweet sorghum [16]. The yield increase effect of crop irrigation is related to the amount of nitrogen fertilizer, and the yield increase effect of nitrogen fertilizer is also related to the amount of irrigation water [17]. Increasing the amount of irrigation increased the proportion of dry matter allocated to the nutrient organs, but the difference was not significant when the soil water content was too high [18], which is basically consistent with the results of this experimental study, indicating that water saving can be achieved through appropriate water deficits. On the basis of the purpose, to obtain higher yield of sweet sorghum stalks. This study found that the dry matter accumulation of sweet sorghum is closely related to the yield, and the dry matter accumulation is mainly concentrated in the jointing stage and heading stage. With the increase of irrigation amount, the dry matter accumulation increased significantly, and the difference in dry matter accumulation and yield of sweet sorghum under W3 and W4 after maturity was not significant. This may be because the excessive irrigation takes away the nutrients in the soil and is too high. Irrigation amount is not conducive to the improvement of lodging resistance of sweet sorghum,

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which leads to insignificant increase in yield; with the increase of nitrogen application, the dry matter accumulation and yield of sweet sorghum increase first and then decrease, which may be due to excessive nitrogen fertilizer inhibiting the roots of sweet sorghum The ability of absorbing water and breathing is basically consistent with the research results of Hu Ruimei [19].

There are many factors that affect the water use efficiency of crops, such as the characteristics of water consumption of crops, environmental factors, cultivation measures, and farming systems [20]. Studies by Chu Pengfei et al [21] and Wang Demei et al [22] have shown that appropriate water stress can improve crop water use efficiency. Zhang Xuezhong et al [23] found that with the increase of total water consumption, crop water use efficiency increased first and then decreased. This study shows that under full irrigation (W4), the water use efficiency of sweet sorghum increases with the increase of nitrogen application, but the growth rate of N2 to N3 is less than that of N1 to N2. Under water shortage, the water use efficiency of sweet sorghum Utilization efficiency first increased and then decreased with the increase of nitrogen application rate; under N1 and N2 nitrogen application rates, the water use efficiency of sweet sorghum first increased and then decreased with the increase of irrigation rate. Under N3 nitrogen application rate, the water use efficiency of sweet sorghum continued to increase with the increase of irrigation amount, which was similar to the results of previous studies. The higher water use efficiency of W4N3 treatment may be due to the fact that sufficient water enhanced the positive water-nitrogen coupling effect, which promoted the absorption of water and nitrogen by sweet sorghum, thereby increasing the water use efficiency. There are many studies on crop water use efficiency, but the research on sweet sorghum is limited to the effects of soil type and irrigation quota on water use of sweet sorghum [24,25], and the interaction of fertilizer and water and nitrogen on water use of sweet sorghum The research is still lacking.

5. CONCLUSION

(1) The effects of water and nitrogen regulation on dry matter accumulation and distribution of sweet sorghum are extremely significant, and the interaction of irrigation and nitrogen application has extremely significant impact on dry matter accumulation and distribution, and the degree of influence is as follows: irrigation> nitrogen application. The dry matter quality of sweet sorghum gradually increased under different water and nitrogen control conditions, and the dry matter accumulation rate was the fastest at the jointing stage-heading stage. With the increase of irrigation amount, the dry matter accumulation of sweet sorghum increased significantly and the distribution ratio of dry matter to the stalk was increased. The dry matter accumulation of stalk W4 treatment was 1.75%, 52.16% and 86.54% higher than that of W3, W2 and W1, respectively, the difference between W3 and W4 treatments was not significant ($P>0.05$); with the increase of nitrogen application, the dry matter accumulation of sweet sorghum increased first and then decreased, both showed: N2>N3>N1.

(2) The effects of water and nitrogen regulation on the fresh weight and dry weight yield of sweet sorghum stalks are extremely significant, and the interaction of irrigation and nitrogen application has a significant impact on the accumulation and distribution of dry matter. The degree of influence is as follows: irrigation>nitrogen application. Proper water and nitrogen regulation can increase the yield by promoting the growth of sweet sorghum, but too high irrigation will not increase the yield of sweet sorghum. Too much nitrogen fertilizer may reduce the soil osmotic potential and cause difficulty in water absorption by the roots of sweet sorghum and reduce yield. With the increase of irrigation amount, the fresh weight yield of sweet sorghum, the fresh weight yield of stalk, and the dry weight yield of shoots all showed an increasing trend. There was no significant difference between the W3 irrigation level and the W4 irrigation level; under the same irrigation level, the medium nitrogen level the yield of sweet

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sorghum increased significantly. Appropriate water and nitrogen regulation are more conducive to water-saving and high-yield. In this experiment, W3N2 treatment can achieve this goal. Among them, W3N2 treatment achieved the highest fresh weight yield (151251.9kg/hm2) and dry weight in the sweet sorghum mature stage. Material yield (45284kg/hm2).

(3) Irrigation and nitrogen application have a very significant interaction on the water use efficiency of sweet sorghum, and the degree of influence is as follows: irrigation>nitrogen application. With the increase of irrigation amount, the water use efficiency of sweet sorghum increased first and then decreased, reaching the maximum under W3 irrigation level. Among them, W3 treatment increased by 4.53%, 27.79% and 45.18% compared with W4, W2 and W1 treatments, respectively, the difference between W3 and W4 treatments was not significant (P>0.05); with the increase of nitrogen application rate, the water use efficiency of sweet sorghum also increased first and then decreased except for full irrigation (W4) treatment. It reached the maximum under the nitrogen application rate. The N2 treatment increased by 23.42% and 14.46% respectively compared with the N1 and N3 treatments; the water use efficiency of the N3 treatment increased by 3.4% and 16.76% compared with the N2 and N1 treatments under full irrigation. The difference between the N3 and N2 treatments was not the same. Significant (P>0.05). Among them, the W3N2 treatment obtained the highest water use efficiency (10.44kg/m3), indicating that the mild water deficit and medium nitrogen conditions are most conducive to the improvement of water use efficiency of sweet sorghum.

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