RESEARCH ON WATER DEMAND RULES AND YIELD OF MULTI-STOREY CROPPING HERBAGE GROUPS UNDER WATER STRESS CONDITIONS

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Abstract. It is greatly significant to implement water-saving irrigation and establish a water-saving system for forage grass, on basis of non-full irrigation principles, in order to meet the demands for forage grass from the rapidly-developing Chinese dairy industry distributing in rural-urban fringes, and improve the utilization efficiency of limited water resources in the central dairy production area of Inner Mongolia. The paper targets four different planting patterns of maize/alfalfa, and discusses water demand rules of herbage groups, variation of evapotranspiration, influence of water shortage at different stages on evapotranspiration, and moisture sensitive period of the forage grass under multi-storey cropping conditions, based on the experimental data of forage multi-storey cropping field under different water stress conditions in the outskirts of Hohhot. According to the results, the change in water demand of maize/alfalfa belt type multi-storey cropping field presents a wavy rule during the whole growth period; compared to evapotranspiration of monocropping maize/alfalfa, the evapotranspiration of maize/alfalfa multi-storey cropping herbage group was not significantly variable. The moisture sensitive period of monoculture maize and alfalfa were respectively heading-milk ripe stage and branching-squaring stage, and the moisture sensitive period of 4//8-type multi-storey cropping pattern is branching-jointing stage.

Keywords: *water-saving irrigation, moisture sensitive period, designed moistening layer, water utilization efficiency, evapotranspiration, moisture sensitive period, water balance equation, modal coefficient*

Introduction

The development level of the dairy industry is deemed as a significant indicator of the quality of modern agriculture in a country, especially animal husbandry. Dairy industry is recognized as a food-saving, economic and efficient industry, among the animal by-products with the highest forage conversion intensity. The World Health Organization regards the average dairy consumption of the population as one of the key indicators to measure the standard of living of the people in a country, and many

countries worldwide, including China. In order to meet the demands for forage grass from the rapidly-developing Chinese dairy industry, it is very significant to research water-saving technologies on basis of non-full irrigation principles, implement water-saving irrigation on dairy forage grass, and improve utilization efficiency of limited water resources in production. Meanwhile, dairy industry mainly distributes in rural-urban fringes, the evapotranspiration for forage production and irrigation has been exhausting urban water resources, the proper distribution of limited water resources will become a critical issue in water management (Zhou et al., 2015; Wang et al., 2003; Chen et al., 1997; Li et al., 2003; Guo et al., 2005; Zhang et al., 2002; Zhao et al., 2008; Liu and Yin, 2013; Liu et al., 2016).

In Hohhot, well-known as “Chinese Dairy City”, the high-quality forage cultivated area reached 173,000 hm² in 2006, accounting for 33% of the city’s total arable land area. The paper analyzes the experimental data of forage multi-storey cropping field under different water stress conditions in the outskirts of Hohhot from 2011 to 2015, discusses water demand rules of herbage groups, variation of evapotranspiration, influence of water shortage at different stages of evapotranspiration, and determines the moisture sensitive period of the forage grass under multi-storey cropping conditions, based on analyzing the forage crops yield under different moisture treatment conditions. The research results provide the basis for the implementation of scientific water management on dairy forage production in Hohhot and even central Inner Mongolia.

Materials and methods

Experimental region

The experiment was conducted in Agricultural Technology Demonstration Park, Xigoumen Town, with coordinates of E111°59′38.97″, N40°37′56.48″. The experimental region is located in semi-arid temperate continental monsoon climate zone, the soil is sandy loam, the mass ratio of organic matter, total nitrogen and total phosphorus is respectively 1.0%, 0.7% and 0.1%, the dry bulk density is 1.4 g/cm³ and the field capacity is 22.2%.

Experimental design

The experimental materials adopt feed & storage dual-purpose type Jinshan No. 1 maize and mow-resistant high-protein content algonquin alfalfa, control index of soil moisture shown in *Table 1*. By adopting field comparison experimental method, total four kinds of crop combinations is planted, including monoculture maize, monoculture alfalfa, 2 rows of maize intercropped with 12 rows of alfalfa (2//12 type), 4 rows of maize intercropped with 8 rows of alfalfa (4//8 type). The total 17 treatment means are implemented, each treatment is made three times, each unit area is 32 m² as shown in *Table 2*. As for 2//12 type, the alfalfa/maize belt width is 2.4 m and 0.8 m, as for the 4//8 type, the alfalfa/maize belt width is 1.6 m, as for monoculture alfalfa/maize field, the belt width is 3.2 m. The climate condition is divided into non-drought and moderate drought, the soil moisture is regarded as the control index. Experimental photograph was shown in *Figure 1*.

Table 1. Control index of soil moisture. (Unit: field capacity %)

Experimental level	Maize monoculture	Alfalfa monoculture	Maize and alfalfa multi-storey cropping
Non-drought	70	65	65
Moderate drought	40~50	40~50	40~50

The moisture is a lower-limit value, the field capacity is an upper limit

Table 2. Experimental design for forage moisture stress

Trt.	Patterns	Moisture treatment			
		Sprouting-tillering period (sprouting (seedling establishment)- branching)	Tillering-jointing period (branching-squaring)	Heading-flowering period (squaring-flowering)	Grouting-mature period
1	Maize monoculture	Non-drought	Non-drought	Non-drought	Non-drought
2		Moderate drought	Non-drought	Non-drought	Non-drought
3		Non-drought	Moderate drought	Non-drought	Non-drought
4		Non-drought	Non-drought	Moderate drought	Non-drought
5		Non-drought	Non-drought	Non-drought	Moderate drought
6	Alfalfa monoculture	Non-drought	Non-drought	Non-drought	
7		Moderate drought	Non-drought	Non-drought	
8		Non-drought	Moderate drought	Non-drought	
9		Non-drought	Non-drought	Moderate drought	
10	2//12 type	Non-drought	Non-drought	Non-drought	
11		Moderate drought	Non-drought	Non-drought	
12		Non-drought	Moderate drought	Non-drought	
13		Non-drought	Non-drought	Moderate drought	
14	4//8 type	Non-drought	Non-drought	Non-drought	
15		Moderate drought	Non-drought	Non-drought	
16		Non-drought	Moderate drought	Non-drought	
17		Non-drought	Non-drought	Moderate drought

Figure 1. Experimental photograph (heading-flowering period of maize and squaring- of alfalfa)

Experimental data acquisition

The meteorological data is obtained and purchased from local meteorological bureau. It is available to sample soil by manual earth boring auger, and determine soil water content by drying and weighing method. The quadrates is adopted to measure the yield before harvest. The tube irrigation method is adopted to record time, the meter is adopted to record irrigation water yield.

Results and analysis

Characteristic of water demand of forage groups under different planting patterns

In accordance with the principle of water balance, in any period of the whole growth term (t), the changes in moisture storage capacity in soil designed moistening layer (h) is expressed by the following water balance equation:

$$W_t - W_0 = W_r + P_0 + K + M + ET_a \quad (\text{Eq.1})$$

In *Equation 1*, W_0 , W_t represents moisture storage capacity in soil designed moistening layer at the beginning of time interval and at any time t ; W_r represents increased moisture storage capacity due to increase of soil designed moistening layer, if the soil designed moistening layer does not change, the option can be ignored; P_0 is rainfall; K is groundwater recharge within the period t , if in the experimental region, the groundwater level is below 10 m within a long period, K should be equal to 0; M is the irrigation water volume within the period t ; ET_a is the actual evapotranspiration.

Table 3 show the actual evapotranspiration and rules of water demand of maize/alfalfa forage group of different cropping patterns under full irrigation conditions according to *Equation 1*.

Table 3. Forage group evapotranspiration of different planting pattern

Trt.	Items		Main technical parameters									
	Alfalfa	Growth period	Crop 1				Crop 2			Crop 3	Whole growth period	
			Seeding-sprouting	Sprouting-branching	Branching-squaring	Squaring-flowering (clipping)	Seedling establishment-branching	Branching-squaring	Heading-flowering (clipping)	Seedling establishment-branching		
		Rainfall (mm)	25.6	34.4	29.2	62.6	134.2	48.4	6.6	16.5		357.5
		Maize	Growth period	Seeding-sprouting	Sprouting-jointing	Jointing-heading	Heading-milking maturity		Milking maturity-soft dough			
Rainfall (mm)	21.5	44.6	48.6	224.6			11.9		351.2			
6	Soil Moisture		19.1-18.4	18.4-16.8	16.8-17.3	17.3~17.3	17.3-20.1	20.1-12.8	12.8-16.2	14.9-15.9		
	Irrigation amount (mm)				100	70			120	70		
	Consumption intensity (mm/d)		2.15	2.65	4.78	6.87	3.25	7.45	6.95	2.15	3.92	
	Evapotranspiration (mm)		32.3	47.7	124.3	137.4	39	111.8	97.3	32.3	726.7	
1	Soil moisture		19.2-20.0	20.0-19.9	19.9-14.0	14.0-14.1			14.1-13.5			
	Irrigation amount (mm)			70	120	180			80			
	Consumption intensity (mm/d)		1.82	3.05	6.65	8.25			6.45		5.95	
	Evapotranspiration (mm)		17.6	92.4	124.5	289.6			76.5		600.6	
10	Soil moisture		20.0-19.6	19.6-17.8	17.8-19.0	19.0-17.5	17.5-20.3	20.3-18.0	18.0-17.4	17.4-16.1		
	Irrigation amount (mm)				70	80		100	100	120		
	Consumption intensity (mm/d)		1.91	3.27	4.78	8.77	2.44	5.59	6.58	3.65	3.49	
	Evapotranspiration (mm)		28.6	58.9	124.4	175.5	29.3	83.9	92.1	54.8	647.3	
14	Soil moisture		18.9-18.4	18.4-16.7	16.7-17.7	17.7-16.5	16.5-20.3	20.3-16.15	16.2-15.4	54.8		
	Irrigation amount (mm)				70	80		100	100	120		
	Consumption intensity (mm/d)		2.0	2.9	5.7	7.6	4.9	7.5	6.9	4.4	3.6	
	Evapotranspiration (mm)		29.8	49.6	98.5	151.0	57.3	112.4	96.3	65.7	660.5	

The percentage of soil moisture in the total soil dry weight, %

Under full-irrigation conditions, the evapotranspiration of monoculture alfalfa is 726.7 mm as the maximum value, and the evapotranspiration of monoculture maize is 600.6 mm as the minimum value, the maize/alfalfa multi-storey cropping evapotranspiration is between the above data, the growing season of monoculture alfalfa within a year is longer than the monoculture maize, the evapotranspiration of monoculture alfalfa is also higher than the monoculture maize during the whole growth period; because mowing is implemented several times a year, evapotranspiration intensity is peaked with alfalfa mowing frequency, each peak occurs in alfalfa squaring-flowering stage, the maximum peak occurs between the first mowing and the Second mowing, during the branching-squaring stage, the evapotranspiration of alfalfa is maximum, accounting for 40.0% of the whole growth period; during the heading-milking stage, the evapotranspiration of monoculture maize is up to 289.6 mm, accounting for 48.2% of the whole growth period. The growing season of monoculture maize is relatively short, during the whole growth period, its total evapotranspiration is also lower than the monoculture alfalfa and multi-storey cropping alfalfa; the water demand rules show a single peak, the consumption intensity during heading-milking stage is maximum. The evapotranspiration of maize//alfalfa belt-type multi-storey cropping during the whole growth is greater than the monoculture maize; and is closer to monoculture alfalfa; the water demand rules of herbage group is impacted by alfalfa mowing, its evapotranspiration intensity is considerably unstable, the fluctuation trend is similar with monoculture alfalfa.

Variation analysis of evapotranspiration of forage grass under multi-storey cropping conditions

Because the dynamic evapotranspiration and evapotranspiration trend of forage grass has changed, the evapotranspiration of maize//alfalfa multi-storey cropping forage grass should not be equal to the sum of evapotranspiration of both two plants, the degree of variation (variability) is calculated by the following formula:

$$C_v = \sum_{i=1}^n \frac{\sqrt{(x - \bar{x})^2}}{x} \quad (\text{Eq.2})$$

In the formula: C_v -variability; x -sample evapotranspiration; $\bar{x}$ -arithmetic mean of the two samples. The evapotranspiration indicators under monoculture conditions are taken as standard samples, the evapotranspiration indicators under multi-storey cropping are taken as comparison samples; C_v - the degree of variation of multi-storey cropping for monoculture.

The evapotranspiration variability calculated by *Equation 2* under the multi-storey cropping conditions are shown in *Table 4*. The results show that the evapotranspiration of forage grass group is not significantly variable from the evapotranspiration of monoculture maize and monoculture alfalfa, the variability is respectively 0.037 and 0.040, however, it is significantly variable, compared with monoculture alfalfa.

Evapotranspiration (ET) of monoculture maize under phased water shortage conditions

Under the maize monoculture conditions, the different water treatment has a significant impact on evapotranspiration. The treatment 4 is the water shortage at

heading-milking stage, the change in total evapotranspiration is the most obvious during the whole growth period, according for 75% of treatment 1. The treatment 2 is the water shortage at sprouting-jointing stage, the change in total evapotranspiration is minimum, according for 85% of treatment 1. In case of water shortage at a certain stage, the treatment may cause the increase of evapotranspiration at the next stage, there is a certain compensation effect, in this experiment, during the sprouting-jointing stage and heading-milking stage, the compensation effect for low moisture treatment is more obvious.

Table 4. Analysis on variation of ET of maize & alfalfa under multi-storey cropping conditions

Samples	Treatments	ET (mm)	C _v
Standard samples	1	600.6	0.0370
	6	726.7	0.0403
Comparison samples	14	660.5	

Water shortage at different growth stages on evapotranspiration of forage groups

It is found from Table 5 that the evapotranspiration at various growth stages under different water treatments is less at the preliminary stage, increase at the interim stage, the late small variation, and then decreases at the later stage, which mainly result from the growth and development of maize plants and influence from environment meteorological factors, the moisture shortage also affects daily evapotranspiration intensity, thereby affects the evapotranspiration at the reproductive stage. Treatment 2 and 3 is the drought conditions respectively at seedling/jointing stage, at this time, the maize seedling size is less, the evapotranspiration is less. At the heading-milking stage, the evapotranspiration of fully-irrigated treatment is maximum, other treatments are water deficit at other growth stages, although after rewatering in this stage, evapotranspiration increases obviously, but is always lower than treatment 1, because the jointing-heading stage is the peak of the growth of maize silage, if water deficit exists during this period, the growth of plants will be seriously affected, resulting in a less silage maize leaf area index, the plant evapotranspiration is less than other treatments; on the other hand, even if the stage is not affected by the drought, but before the stage have been affected, resulting in poor plant growth, and the evapotranspiration intensity and evapotranspiration will be ultimately affected in the later stage of treatment.

Table 5. Maize straw of different water treatment on evapotranspiration

Trt	Seeding-sprouting		Sprouting-jointing		Jointing-heading		Heading-milking maturity		Milking maturity-soft dough		Whole growth period (mm)
	ET (mm)	Modal coefficient (%)	ET (mm)	Modal coefficient (%)	ET (mm)	Modal coefficient (%)	ET (mm)	Modal coefficient (%)	ET (mm)	Modal coefficient (%)	
1	17.6	2.9	92.4	15.4	124.5	20.7	289.6	48.2	76.5	12.7	600.6
2	10.2	2	23.0	4.5	152.6	29.9	246.1	48.2	78.6	15.4	510.5
3	8.8	2	66.2	15.1	52.2	11.9	247.3	56.4	64.0	14.6	438.4
4	8.6	1.9	63.5	14.1	114.9	25.5	134.2	29.8	129.3	28.7	450.5
5	9.1	1.9	67.3	14	107.2	22.3	240.7	50.1	56.2	11.7	480.5

Evapotranspiration of monoculture alfalfa under phased water shortage conditions

Table 6 shows, the alfalfa high evapotranspiration period is between in the first crop and the second crop, in the stage, the evapotranspiration accounts for 47.82% and 40.49% of total amount of the whole growth period, under full-irrigation conditions. The low moisture treatments in seedling (seedling establishment)-branching, branching-squaring, squaring-flowering, and other growth stages has a great influence on the total evapotranspiration during the whole growth period, compared to treatment 1, the low moisture treatment at the branching-squaring stage decreases by 20%; at seedling (seedling establishment)-branching stage, the total evapotranspiration of whole growth period changes less, however, it can decrease by 18%, compared with treatment 6.

Table 6. *Evapotranspiration of monoculture alfalfa and maize/alfalfa intercropping at different water treatments*

Trt	Crop 1		Crop 2		Crop 3		Total ET (mm)
	ET (mm)	Modal coefficient (%)	ET (mm)	Modal Coefficient (%)	ET (mm)	Modal coefficient (%)	
6	347.5	45.9	294.3	38.8	84.9	11.2	726.7
7	250.1	40.5	266.2	43.1	76.6	12.4	592.9
8	270.2	44.7	206.0	34.1	103.5	17.1	579.7
9	262.1	43.1	229.5	37.8	91.5	15.1	583.1
14	326.5	43.0	276.9	36.5	57.1	7.5	660.5
15	279.7	42.6	257.8	39.2	33.8	5.1	571.3
16	303.8	45.5	235.9	35.3	40.6	6.1	580.3
17	275.5	42.9	247.3	38.5	35.0	5.5	557.8

Evapotranspiration of 4//8 type at intercropping stage under water shortage conditions

Table 6 shows, as same as monoculture alfalfa, the alfalfa high evapotranspiration period is between in the first crop and the second crop under full-irrigation conditions, however, the evapotranspiration ratio in the second crop is higher than monoculture alfalfa, in the stage, the evapotranspiration accounts for 49.43% and 41.92% of total amount of the whole growth period. The evapotranspiration of maize//alfalfa multi-storey cropping forage grass should not be equal to the sum of evapotranspiration of both two plants, this shows that the planting pattern changes growth environment, the field evapotranspiration changes. Under full irrigation conditions, the low water treatment has a greater impact on branching-squaring and squaring-flowering stages; and has poor impact on emergence-branching stage.

Influence of different water treatments on forage yield

Table 7 shows, at different growth stages, different forages show various response to water stress, but which is eventually reflected by forage yield differences. Ass for monoculture maize, the influence of water shortages on yield reduction is the greatest at heading-milking stage, and is the lowest at sprouting-jointing stage. The influence of phased water shortage on the yield (grain) is in compliance with the following rules: Treatment 4 > Treatment 3 > Treatment 5 > Treatment 2, the maize requires less moisture at seedling stage; at the jointing stage, the impact of water deficit on yield is

greater, in case of water shortage at jointing period, the yield reduction rate is 47.2%; at the heading and milking stages, the maize transfers from vegetative growth to reproductive growth, leaf area index and evapotranspiration reach its highest value during the whole period, reproductive growth and metabolism is being vigorous; at flowering, pollination and milking stages, the output efficiency is the highest, lack of water has a greatest impact, the yield reduction rate is up to 51.7%; after soft dough stage, the influence of water deficit on yield decreases gradually. At different stages, the water deficit treatment does not significantly affect moisture production efficiency of monoculture maize, which is basically the same between Treatment 1 and Treatment 2, Treatment 3 is slightly lower than Treatment 5, the influence of Treatment 4 is maximum.

Table 7. Analysis on forage yield under different water treatments

Treatments	ET (mm)	Total yield (dry weight kg/hm ²)	Moisture production efficiency (kg/m ³)	Yield reduction rate (%)
1	600.6	13250.0	2.2	—
2	510.5	11316.7	2.2	17.1
3	438.4	9000.0	2.1	47.2
4	450.5	8733.4	1.9	51.7
5	480.5	10316.7	2.1	28.4
6	726.7	21150.0	2.9	—
7	592.9	16031.7	2.7	24.2
8	579.7	13472.6	2.3	36.3
9	583.1	14212.8	2.4	32.8
14	660.5	2636.8	0.399	—
15	571.3	2136.8	0.289	19.0
16	580.3	1706.9	0.294	35.3
17	557.8	1693.9	0.304	35.8

As for monoculture alfalfa, when the water shortage is implemented at emergence-branching stage (the lower limit of soil moisture content is lower than 50%), the impact on the yield is minimum, the yield reduction rate is 24.2%, indicating under normal emergence seedling conditions, appropriate water shortage does not impact later yield; the branching- squaring stage is a critical period of alfalfa physiological change, water shortage has the greatest impact on later yield, the yield reduction rate is 36.35%; during the squaring-flowering period, the influence of water shortage on the total yield decreases, the yield reduction rate is 32.8%. under different moisture treatment conditions, if the water supply is sufficient, the water production efficiency of monoculture alfalfa is the highest, and 6.89% higher than that of water shortage at sprouting-branching stage, 20.69% higher than that of water shortage at branching-budding stage, and 17.24% higher than that of water shortage at budding-- flowering stage.

As for the intercropping maize/alfalfa, alfalfa has a longer growth period, under non-full irrigation experimental design is mainly base on phased water supply in alfalfa growth period. By conversion to the crude protein content in maize/alfalfa final product within one year, it is available to conclude that the water shortages at squaring-

flowering stage has the greatest impact on crude protein yield under intercropping conditions under different water treatments, which is different with the maximum influence period from water shortage of monoculture alfalfa of branching-squaring stage, indicating two kinds of forages jointly change the rules of nutrition production of the whole groups of plants in farmland.

Conclusions

As the main dairy forage, maize and alfalfa are completely different in water demands. During the whole growth period, the water demand rules of maize is a single peak parabola; during a growing season, the water demand rules of alfalfa shows multiple peaks as times of mowing increase; The evapotranspiration of maize//alfalfa multi-storey cropping forage grass should not be equal to the sum of evapotranspiration of both two plants, the rules of water demand change greatly, showing a wavy undulating state. compared to evapotranspiration of monoculture maize and monoculture alfalfa, the variation of evapotranspiration of maize//alfalfa multi-storey cropping forage groups is not very significant.

As for monoculture maize, the influence of phased water shortage on the yield is maximum at the jointing-heading and heading-milking stages (moisture sensitive period); the influence of phased water shortage is minimum at emergence-jointing stage; as for monoculture alfalfa, during the squaring-flowering and branching-squaring period (moisture sensitive period), the influence of phased water shortage on the yield is maximum; at emergence (seedlings establishment)-jointing stage, the influence of phased water shortage is minimum; as for 4//8-type multi-storey cropping, at the branching-jointing stage of alfalfa, the influence of phased water shortage on the yield is maximum, which is greatly different with monoculture alfalfa.

In future studies, in order to meet the requirements of large-scale popularization and application of multi-storey cropping, further test deepening, technology integration and demonstration of various technologies still need to be implemented., technological maturity and farmers' planting level need to be improved, and technological maturity and farmers' planting level need to be improved.

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REFERENCES

- [1] Chen, Y., Sun, J. (1997): Research on soil moisture control standards of water-saving irrigation. – *Irrigation and Drainage* 16(1): 24-28.
- [2] Guo, K., Li, H., Shi, H. et al. (2005): Research on optimization of water-saving irrigation system and evapotranspiration of forage crop in Mu Us sandland. – *Irrigation and Drainage* 2: 24-27.
- [3] Li, J., Wu, F., Fan, Y. (2003): Research on water-saving irrigation index and development mode. – *Water-Saving Irrigation* 5: 14-15.

- [4] Liu, H., Yin, C., Wei, Y., Zhang, R., Gao, T. (2016): Water production function of artificial grassland crop in arid desert area of Northern Xinjian. – *Agric. & Life Sci., Journal of Zhe Jiang University* 42(2): 169-178.
- [5] Wang, X., Ma, Y., Li, J. et al. (2003): Nutrients and biological characteristics of alfalfa. – *Pratacultural Science* 10: 39-40.
- [6] Zhang, X., Pei, D., Hu, C. (2002): Research on irrigation index of winter wheat and summer maize on Taihang Piedmont Plain. – *CSAE* 18(6): 36-41.
- [7] Zhao, S., Guo, K., Su, P. (2008): Comprehensive benefit evaluation on dairy forage under different cropping patterns. – *Water Economy* 26(6): 41-44.
- [8] Zhou, X., Luo, Q., Qu, B. (2005): Current situation and future development trends of China's dairy industry. – *Contemporary Animal Husbandry* 12: 1-3.
- [9] Liu, H., Wei, Y., Guo, K. (2013): Water requirement and its law of silage corn in northern Xinjiang arid desert grassland. – *Chinese Agricultural Science Bulletin* 29(33): 94-100.