The effects of deficit irrigation on Water-use efficiency, yield, and quality of forage pearl millet

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Abstract

Water limitation, water stress and so deficit irrigation are common phenomena in the Middle East. Although pearl millet has been known as an important subsistence cereal for dry areas of the semi-arid tropical regions, nowadays it is cultivated across a wide range of environments ranging from extremely stressful to favourable. To assess the effect of deficit irrigation on water-use efficiency, yield, yield components and forage quality of pearl millet at different growth stages, a field experiment was conducted on Research Farm of Karaj Agriculture Faculty of Tehran University in 2002. The irrigation intervals (weekly irrigation interval, 11-day irrigation interval and 15-day irrigation interval) were assigned to the main plots and irrigation volumes (Control (equal to calculated water requirement), moderate water stress (75% of water requirement) and severe water stress (50% of water requirement)) were assigned to the sub-plots. The crop was cut three times during the growth cycle. Leaf and stem characteristics (biomass, digestible dry matter, crude protein, water-soluble carbohydrates, acid detergent fiber, ash, digestible crude protein, and metabolism energy) were measured separately, other characteristics measured were water-use efficiency, plant height and forage yield. The F.A.O. Penman-Monteith equation was used for estimating crop water requirement and Near Infrared Spectroscopy (NIR) was used to estimate the quality parameters. The results showed that irrigation intervals had significant effects on total protein and digestible crude protein; on the other hand irrigation volume had significant effects on yield, plant height, water-use efficiency, metabolism energy, digestible crude protein, digestible dry matter, crude protein, water soluble carbohydrates, acid detergent fiber and biomass. It can be concluded that irrigating with 75% of the estimated water requirements of pearl millet, the quantity and most of the qualitative traits of dry forage does not change, and water-use efficiency increases with higher levels of water stress.

Media summary

Pearl millet can be considered as a suitable forage crop for water stressed and normal conditions in semi-arid regions such as the Middle East and especially Iran.

Key Words

Irrigation interval, Drought stress, Near Infrared Spectroscopy, Forage quality, *Pennisetum americanum.*

Introduction

The physical environment can be a major limiting factor in growth, productivity and survival of plants. Water stress is usually the main physical limitation to forage yield. It has a considerable effect on forage growth, development and quality. Water limitation and water stress are common phenomena in the Middle East; therefore, developing and achieving proper strategies to overcome these problems is a necessity for the region. Although, pearl millet has been known as an important subsistence cereal for dry areas of the semi-arid tropical regions, nowadays it is cultivated across a wide range of environments ranging from extremely stressful to favourable. The objective of this research was to study the effects of timing and frequency of deficit irrigation on pearl millet yield, forage quality and water-use efficiency at different growth stages under a semi-arid environment of Iran.

Methods

A field experiment was conducted during the dry season on the research farm of Tehran University in 2002. The treatments were arranged as split-split-plots per location and time. The data were analysed and statistically compared using on Randomized Complete Block Design with four replications. The irrigation intervals (weekly irrigation interval, 11-day irrigation interval and 15-day irrigation interval) were assigned to the main plots and irrigation volumes (Control (equal to calculated water requirement), moderate water stress (75%of water requirement) and severe water stress (50%of water requirement)) were assigned to the sub-plots. The crop was cut three times during the growth cycle. Leaf and stem characteristics including yield, water use efficiency (WUE) and forage quality indices were measured. The Penman-Monteith equation was applied to determine water requirement of pearl millet, and Near Infrared Spectroscopy (NIR) was used to estimate the quality parameters.

Results

As can be seen in figure 1, by increasing the deficit level of irrigation , the fresh weight of forage decreased. Many other researchers have observed the same phenomena.

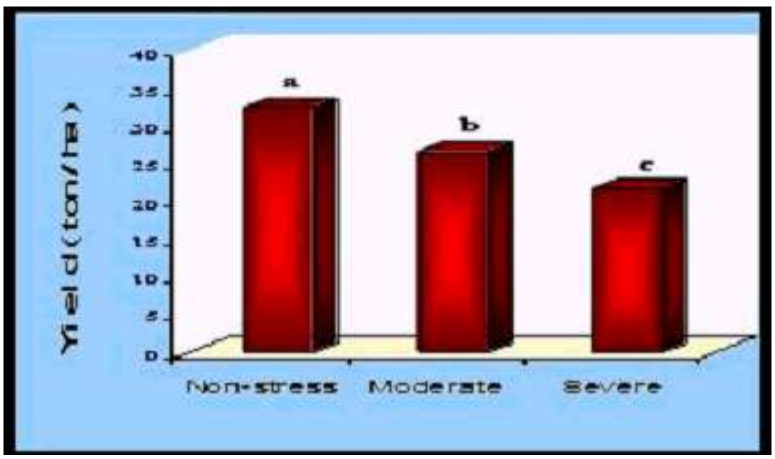

Figure 1. The average of fresh forage yield in different water stress levels (means followed by a similar letter

are not significantly different at the 5% level of probability)

By considering dried forage weight, slightly different results were observed (Figure 2). There were no significant differences between control (Non-stress) and moderate stress (75% of water requirements), but the amount of dried forage decreased significantly under severe stress (50% of water requirements).

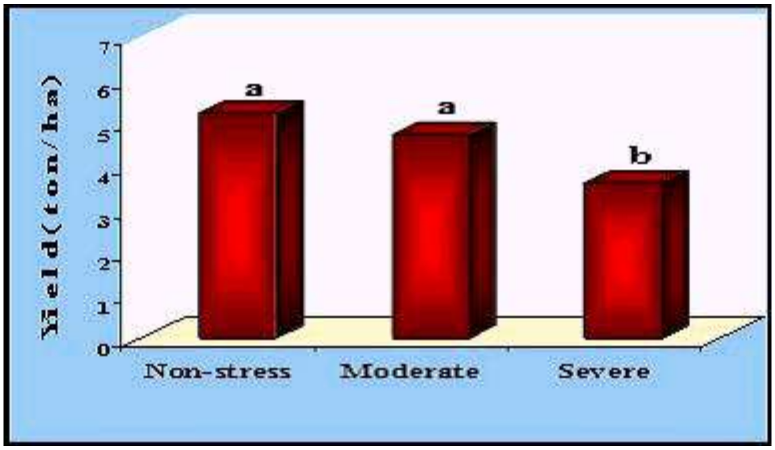

Figure 2.The average of dry biomass in different water stress levels (means followed by a similar letter are

not significantly different at the 5% level of probability)

On the other hand, water use efficiency (WUE) increased as a result of decreasing the volume of irrigation (Figure 3), This result is in accordance with many other observations. (e.g. Mastrorili et al. 1999).

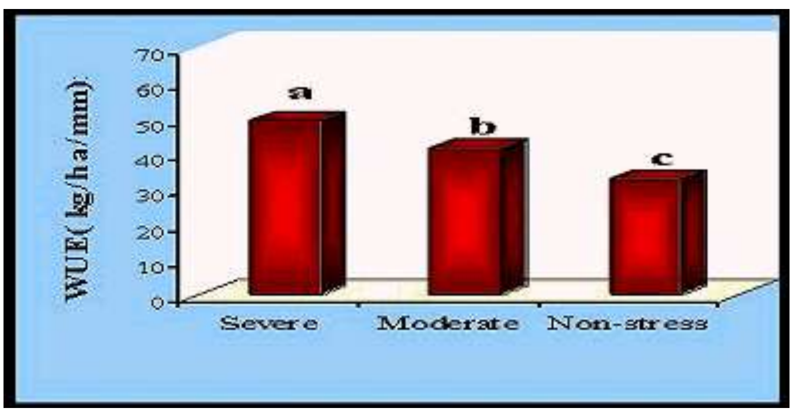

Figure 3. The average of Water-Use Efficiency under different water stress levels (means followed by a similar letter are not significantly different at the 5% level of probability)

Considering different harvests, the third harvest had the highest water use efficiency (Figure 4); this might be because of decreased evapotranspiration at the end of growing season.

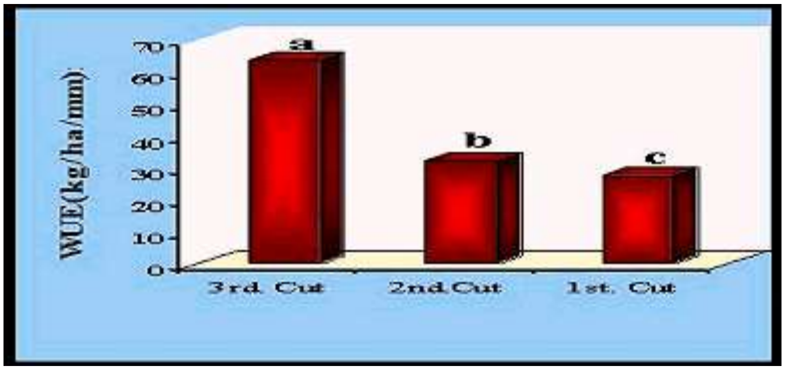

Figure 4. The average of Water-Use Efficiency at different harvests over all stress levels (means followed by a similar letter are not significantly different at the 5% level of probability)

The effects of water stress on quality of forage are shown in Table.5. By decreasing the volume of irrigation, crude protein concentration of stem increased, while it was decreased in leaves resulting in no significant difference in total crude protein concentration under different water stressed conditions. Higher levels of water stress decreased the amount of structural carbohydrates, so water-soluble carbohydrates of stem increased (because it contains non-structural carbohydrates), while acid detergent fiber (ADF) decreased (because of decreasing cellulose and lignin), but water-soluble carbohydrates and ADF of leaves did not change under different stress conditions. Water stress significantly increased the digestible dry mater in the stem, but decreased it in leaves.

Table 1. The average of forage quality parameters percentage in different water stress levels

Forage Quality Parameters	Severe stress		Moderate stress		Non-stress	
	Leaf	Stem	Leaf	Stem	Leaf	Stem
Digestible Dry Matter (%)	57.31^{c}	64.95^{a}	58.34^{b}	63.8^{b}	60.02^{a}	63.01^{b}
Crude Protein (%)	16.5^{b}	9.88^{a}	18.31^{a}	9.11$^{a\ b}$	18.89^{a}	8.7^{b}
Water-Soluble Carbohydrates (%)	5.72^{a}	15.77^{a}	5.38^{a}	14.01^{ab}	4.98^{a}	12.11^{b}
Acid Detergent Fiber (%)	39.99^{a}	31.99^{b}	38.43^{a}	33.01^{a}	37.91^{a}	33.76^{a}

Means followed by a similar letter are not significantly different at the 5% level of probability.

On the other hand, the quality of forage evaluated during different harvests, (Table 2), shows the first harvest had the highest percentage of crude protein and acid detergent fiber (ADF) both in leaves and stem, and in contrast, the third harvest had the maximum percentage of the digestibility, dry mater and water-soluble carbohydrates in leaves and stem.

Table 2. The average quality parameters of all stress levels at different harvests

Forage Quality Parameters	First Cut		Second Cut		Third Cut	
	Leaf	Stem	Leaf	Stem	Leaf	Stem
Digestibility Dry Matter (%)	57.04[b]	61.95 [b]	59.01 [a]	64.33 [a b]	60.06[a]	65.55 [a]
Crude Protein (%)	19.22 [a]	12.51 [a]	17.63 [b]	8.13 [b]	16.23 [c]	7.01 [c]
Water-Soluble Carbohydrates (%)	3.32 [c]	12.53 [b]	5.58 [b]	13.47 [b]	7.16 [a]	17.07 [a]
Acid Detergent Fiber (%)	40.59 [a]	37.9 [a]	38.34 [b]	31.07 [b]	36.19[c]	30.78 [b]

Means are followed by a similar letter are nit significantly different at the 5% level of probability.

Conclusion

It can be concluded that with 75% of estimated water requirements of pearl millet, the quantity and most of the qualitative traits of dry forage do not change, and water-use efficiency increases with higher levels of water stress, therefore pearl millet can be considered as a suitable forage crop for water stressed and normal conditions in Iran.

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