

Water Use in Relation to Management of Blue Panicgrass

(*Panicum antidotale* Retz.)¹

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Highlight

Efficiency of water use was determined for blue panicgrass grown in the field. Management treatments were soil-moisture stress, clipping height, and maturity stage. Water-use efficiency was expressed as the number of units (kg) of water per unit (kg) of forage dry-weight produced. Blue panicgrass showed a relatively broad tolerance to high soil-moisture stress. Efficient use of water and root weight decreased when soil-moisture stress was increased, while dry-weight of forage was unchanged. The 30-cm clipping height, when the majority of seed heads emerged from the boot, was most efficient in water use; gave the highest production of forage; produced the highest percentage protein; and produced the most roots. Two noteworthy findings were: a) the most efficient use of water and the highest forage production were obtained from the same management; and b) the highest protein percentage and the highest forage production were obtained from this same management. This performance of blue panicgrass where highest production of forage, highest percentage of protein, and most efficient use of water is contrary to the performance of some crops, because these responses rarely occur for the same management.

The maximum production derived from any crop depends largely on the available moisture in the soil. Hobbs, Krogman, and Sonmor (1963) reported that crops vary in their yield response to various soil-moisture levels in the root zone and that consumptive use of water was highest at the highest levels of soil moisture. Maximum yields of most crops occurred when the maximum available moisture was at or below 50%.

Bennett et al. (1964) showed that forage yields of 3 annual grasses increased with increased soil moisture. Burton, Prine, and Jackson (1957) found that 'Coastal' and 'Suwannee' bermudagrass (*Cynodon dactylon* L.) were more efficient in water use under soil-moisture stress compared to abundant soil moisture conditions. However, pangolagrass (*Digitaria decumbens* Stewt), bahiagrass (*Paspalum notatum* Flugge), and common bermudagrass were less efficient in water use under stressed soil moisture conditions.

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Bennett and Doss (1963) showed that 8 cool-season perennial forage species increased in productivity through the soil-moisture treatment which allowed for depletion of 63% of the available moisture in the root zone before irrigation. However, the means for yield and water used, reported by these authors, indicated that all species were more efficient when 80% of the available soil moisture was depleted before irrigation.

Stanhill's (1957) review showed that the majority of investigators associated increased yield with increased availability of soil moisture. However, there were exceptions in which no significant responses were noted. Keller (1954) concluded that orchardgrass (*Dactylis glomerata* L.) was more efficient when soil moisture was held near field capacity. However, Letey and Blank (1961) reported that when watering was delayed, less water was used to produce a gram of dry matter regardless of the environment. Luebs and Laag (1967) suggested that greater efficiency of water use was realized when 'Arivat' barley (*Hordeum vulgare* L.) was irrigated at the heading period.

It is evident from the literature that considerable variation occurs for efficiency of water use and yield under different irrigation schedules. The objectives of this study were to determine the water-use efficiency of blue panicgrass (*Panicum antidotale* Retz.) and to relate the efficiency to previously reported data on forage yield, forage quality (crude protein), and root development under different management practices, Wright (1962a, 1962b).

Materials and Methods

The studies were conducted at the Tucson Plant Materials Center, Soil Conservation Service, Tucson, Arizona in Comoro sandy loam soil. Seed of 'A-130' blue panicgrass was used to establish all plots.

Soil-Moisture Stress

A randomized-block design with four replications was used. Treatments of soil-moisture stress were applied in separate plots. The same treatments were on the same plots each year. Each plot was leveled, surrounded by a border ridge, and irrigation water was applied by flooding. Water was transported through a portable aluminum pipe with gated-pipe adapters and distributed to each plot through canvas tubes. Plots were 6-rows wide (46-cm spacing, 18 inches) and 4.6-m (15 feet) long. The forage sampling area was 2.7 m (9 feet) of the two-center rows. The planting was established through one growing season and sampled in 1958 and 1959. Soil-moisture treatments were achieved by allowing the soil to dry to the wilting point (approximately 50,000 ohms) at depths of 15, 30, 45, and 60 cm. A moisture meter was used to determine the electrical resistance (ohms) of gypsum soil blocks that were buried near the center of each plot. When all plots of a stress treatment for all replications reached the wilting point, irrigation water was applied to bring the soil to field capacity.

The plots that were stressed to a depth of 15 cm received six irrigations with a total of 1274 kg of water for the forage sampling area each year. The plots stressed to 30 cm received five irrigations with a total of 1211 kg of water in 1958 and 1242 kg of water in 1959. The plots stressed to 45 cm received four irrigations with 1211 kg of water in 1958, and five irrigations with 1306 kg of water in 1959. The plots stressed to 60 cm received four irrigations with 1370 kg of water for the sampling area each year. Kilograms of irrigation water included precipitation during the growing season. Forage was harvested when the majority of seed heads had emerged from the boot and was independent of moisture treatments. Clipping height was 15 cm above the soil. A total of 450 kg of N per hectare was split and applied at the beginning of the growing season and at mid-season as a constant treatment each year.

Clipping Height and Stage of Maturity

A split plot design with four replications was used with maturity stages as whole plots. Clipping heights were 7.5, 15.0, 22.5, and 30.0 cm. Maturity stages at the time of harvest were: (a) when a majority of the seed heads had emerged from the boot; (b) when a majority of the seed heads were pollinating; and (c) when a majority of the seed heads were in the soft-dough stage. These stages were designated emergence, pollination, and soft-dough, respectively. The planting was established in a level irrigation border with 46-cm (18-inch) row spacing. Whole plots were 6-rows wide and 12.8 m (42 feet) long. Subplots were 4.3 m (14 feet) long. The forage sampling area for subplots was 2.4 m (8 feet) of the two center rows. Irrigation was applied by flooding at approximately 2-week intervals. Plots received 9 irrigations in 1958, and 8 irrigations in 1959, which included the recharge irrigation in the spring each year. Irrigation water applied was 2095 kg per plot (sampling area) in 1958 and 2051 kg per plot (sampling area) in 1959. Total water applied included precipitation during the growing season. Number of harvests for maturity stages were 6 and 5 for emergence, 5 and 5 for pollination, and 4 and 4 for soft-dough in 1958 and 1959, respectively. A total of 900 kg of N per hectare was split and applied at the beginning of the growing season, and at mid-season, as a constant treatment each year, Wright (1962b). During the second year, forage harvested from all plots was analyzed for crude protein.

Root Weight

Four soil-core samples were taken the second year at random from the center of the grass row within each plot of the soil-moisture stress and clipping-height (subplot) studies. Samples were collected to a depth of 60 cm in 15-cm increments. A tube 2 cm in diameter was used. The soil-core samples were composited for each treatment. The above-ground portion of the grass plant was removed and the soil-core samples were placed in paper bags, labeled, and air-dried. Samples were soaked in water and washed through a 30 by 30 mesh sieve. A mist spray was used to remove the soil. After the roots had air-dried, rhizomes were removed. Roots were placed on filter paper, oven-dried at 100 C, and weighed on an analytical balance.

Results and Discussion

Water-use efficiency values were calculated from the dry-weight forage yield and the amount of ir-

Table 1. Water-use efficiency (kg/kg¹) and forage dry-weight (MT/ha) of blue panicgrass at four depths (cm) of soil-moisture stress, 1958 and 1959.

Stress depth	Forage dry-weight		Water-use efficiency	
	1958	1959	1958	1959
15	39.2 a	32.3 a	146 a	164 a ²
30	37.4 a	29.1 b	147 a	192 b
45	40.4 a	29.6 b	135 a	198 b
60	43.5 a	27.8 b	144 a	220 c

¹Water-use efficiency values were expressed as the number of units (kg) of water per unit (kg) of forage dry-weight produced.

²Mean values of water-use efficiency and forage dry-weight within years followed by the same letter were not significantly different at the 1% level.

rigation water applied. Values were expressed as the number of units (kg) of water per unit (kg) of dry matter produced.

Soil-Moisture Stress

Efficiency of water use and forage dry-weight did not differ significantly among stress treatments in 1958. In 1959 efficiency and dry-weight values were less and significantly different (Table 1). A combined analysis of variance showed a significant increase in water-use efficiency and a significant reduction in forage dry-weight the second year. The 15-cm stress treatment the second year was the most efficient for water use and the highest forage producer. Water-use efficiency decreased when the depth of soil-moisture stress was lowered. The 60-cm stress treatment was least efficient and significantly different from the other stress treatments; yet, the forage dry-weight was not significantly reduced the second year.

During the second year, when soil-moisture stress was increased, the plants were progressively less efficient in water use. Blue panicgrass had a relatively broad tolerance to high soil-moisture stress (Table 1). This was expressed by low use of soil moisture and high forage yield.

Clipping Height and Stage of Maturity

Significant differences were found among maturity stages for efficient use of water and forage dry-weight (Tables 2 and 3). The emergence- and pollination-maturity stages were more efficient in water use and produced more forage than the soft-dough stage for the first year. The second year the emergence stage was the most efficient in water use and produced the highest forage dry-weight. When maturity stage was considered as a separate variable for both years, the emergence-maturity stage was most efficient in use of water and produced the highest forage yield.

Different clipping heights affected water-use efficiency and forage dry-weight for both years (Tables 2 and 3). The 30-cm clipping height was

Table 2. Water-use efficiency (kg/kg¹) and forage dry-weight (MT/ha) of blue panicgrass at three maturity stages and four clipping heights (cm), 1958.

Maturity stage	Clipping height				Maturity stage mean
	7.5	15.0	22.5	30.0	
Water-use efficiency					
Emergence	287	269	225	206 ²	247 a ³
Pollination	262	230	234	232	239 a
Soft-dough	257	272	259	255	261 b
Clipping height mean	269 b	257 b	239 a	231 a ³	
Forage dry-weight					
Emergence	32.9	35.8	42.0	45.6 ²	39.2 a ³
Pollination	36.0	41.0	40.2	40.8	39.5 a
Soft-dough	36.2	34.7	36.5	36.9	35.9 b
Clipping height mean	35.0 b	36.8 b	39.5 a	41.2 a ³	

¹Water-use efficiency values were expressed as the number of units (kg) of water per unit (kg) of forage dry-weight produced.

²Comparison of interactions by LSD's at the 1% level of significance were 17.7 and 4.62 for clipping heights at a maturity stage, and 15.8 and 3.41 for maturity stages at a clipping height for water-use efficiency and forage dry-weight means, respectively.

³Maturity stage means and clipping height means of water-use efficiency and forage dry-weight within years opposite the same letter were not significantly different (5% level for maturity stage and 1% level for clipping height).

most efficient in water use and gave highest forage dry-weight for both years, but this clipping height was not different from the 22.5-cm clipping height the first year. The range in water-use efficiency and forage dry-weight among clipping heights was amplified the second year. Forage dry-weight was reduced by 26% when plots were clipped at 7.5 cm compared to 30 cm. The first year the reduction was 14%. The effect of close clipping was cumulative; thus, the differences among clipping heights in water-use efficiency and forage production could be greater in subsequent years with continuous clipping height treatments.

The interaction, maturity by clipping height, was significant for both years (Tables 2 and 3). The emergence-maturity stage, when clipped at 30 cm, was the most water-use efficient and the highest forage-production treatment among all combinations of maturity stages and clipping heights for both years.

Protein accumulation was significantly influenced by stage of maturity. Protein content was highest at the emergence-maturity stage (18.1%) and significantly decreased as the forage matured to the pollination- (15.4%) and soft-dough- (13.6%) maturity stages. Protein percentage was not influenced by clipping height and the interaction, maturity by clipping height, was not significant.

Two findings were noteworthy. First, the most efficient use of water and the highest forage pro-

Table 3. Water-use efficiency (kg/kg¹) and forage dry-weight (MT/ha) of blue panicgrass at three maturity stages and four clipping heights (cm), 1959.

Maturity stage	Clipping height				Maturity stage mean
	7.5	15.0	22.5	30.0	
Water-use efficiency					
Emergence	291	258	232	195 ²	245 a ³
Pollination	332	304	243	232	278 b
Soft-dough	277	279	259	238	263 b
Clipping height mean	300 d	280 c	245 b	221 a ³	
Forage dry-weight					
Emergence	31.6	35.9	39.6	47.4 ²	38.6 a ³
Pollination	28.0	30.3	37.8	39.7	34.1 b
Soft-dough	33.2	33.0	35.5	38.8	35.0 b
Clipping height mean	30.5 d	33.2 c	37.7 b	42.1 a ³	

¹Water-use efficiency values were expressed as the number of units (kg) of water per unit (kg) of forage dry-weight produced.

²Comparison of interactions by LSD's at the 1% level of significance were 15.6 and 2.87 for clipping heights at a maturity stage, and 13.3 and 2.56 for maturity stages at a clipping height for water-use efficiency and forage dry-weight means, respectively.

³Maturity stage means and clipping height means of water-use efficiency and forage dry-weight within years opposite the same letter were not significantly different (1% level).

duction were obtained from the same management when plants were clipped at 30 cm and when a majority of the seed heads had emerged from the boot (emergence-maturity stage). This may be considered contrary to the performance of some crops where increased production was associated with less efficient water use. Second, the emergence-maturity stage gave the highest forage and protein yield, which along with 30-cm clipping height, was the superior management for efficient use of water. This performance of blue panicgrass may be considered contrary to most forage crops, where highest production of forage dry-weight and protein rarely occur at the same stage of development.

Root Weight

The weight of roots was 2.2, 2.0, 1.9, and 1.9 g for the 15-, 30-, 45-, and 60-cm depths of soil-moisture stress, respectively, for the second year of the study. A significantly-negative linear-response was determined for root weight to increased soil-moisture stress. Highest root weight, highest dry-weight of forage, and highest efficiency of water use (Table 1) were obtained from the 15-cm treatment of soil-moisture stress. Thus, water-use efficiency, forage dry-weight, and root weight were decreased when soil-moisture stress was increased.

Weight of roots was 1.1, 1.2, 1.4, and 1.7 g for the 7.5-, 15.0-, 22.5-, and 30.0-cm clipping heights, respectively, for the second year of the study. A significantly-negative linear-response was deter-

mined for root weight to higher clipping height. Highest root weight, highest dry-weight of forage, and highest efficiency of water use (Table 3) were obtained from the 30-cm clipping height. Thus, water-use efficiency, forage dry-weight, and root weight were decreased when clipping height was decreased.

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