Effect of temperature on seedling growth characteristics of *Panicum maximum*

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Abstract

Five cultivars of guinea grass (*Panicum maximum*) (TD 58, Gatton, Natsukaze, Natsuyataka and Natsukomaki) were studied in the controlled-environment room at the National Agricultural Research Center for Kyushu and Okinawa Region, Kumamoto, Japan for 6 weeks following seedling emergence. All the guinea grass cultivars were grown at 3 temperature regimens, *viz.* 25/15, 30/20 and 30/25°C day/night. The objectives of this experiment were to determine the response of guinea grass cultivars to different seasonal temperature conditions. The results showed that the growth and development of all cultivars in terms of plant height, leaf area and plant dry matter yield were severely reduced at the lowest temperature (25/15°C). All cultivars responded to increasing temperature between 25/15 and 30/20°C for all attributes, except tiller number and leaf number. In terms of leaf area and total plant dry weight, cultivar Natsukaze had the best performance under low temperature followed by cultivar Natsukomaki. All cultivars grown at 25/15°C had higher N, Zn, Mn, and Cu concentrations than at 30/20 or 30/25°C while I and Co were variable.

Under field conditions in Thailand at 3 months after planting in the cool season, Natsukaze produced the highest dry matter yield followed by TD 58, Gatton and Natsuyataka.

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Introduction

Pasture production in Thailand is low during the 6-month dry season (November–April) due mainly to lack of precipitation. Even when soil moisture is adequate during this period, the growth of these species is still significantly depressed (Hongyantarachai *et al*. 1992). An additional factor is the relatively cool conditions from November–early February when ambient temperature can fall to 14°C which is below the optimum level for growth of tropical grasses (35–40°C) (Whiteman 1980). One approach to increase winter pasture production is to grow areas of special-purpose pastures of temperate grasses to help meet annual feed demands during this cool period. However, survival of these grasses is poor when temperatures increase markedly in late February (Tudsri and Wongsuwan 1997).

The search for new species, particularly for those with higher winter yield, is continuing. Variation in responsiveness to temperature, if present, might be used to select new species that will grow more rapidly under lower temperatures. The aim of this study was to examine the effect of temperature on the morphology and growth of guinea grass (*Panicum maximum*) cultivars during the early stages of development. The first experiment was conducted in a controlled-environment room in Japan and the second under field conditions during the dry cool season (December–February) in Thailand.

Materials and methods

Controlled environment

The experiment was conducted at the National Agricultural Research Center for Kyushu and Okinawa Region, Kumamoto, Japan. Five guinea grass cultivars were studied including: TD 58, Gatton, Natsukaze, Natsuyataka and Natsukomaki. All guinea grass seed was planted directly into pots (25 cm diameter) containing Andosal soil which consists of volcanic ash and is classified as a fine sandy soil. A basal fertiliser of N, P and K was applied at 100 kg/ha for each nutrient. Germinated seedlings were transferred to the growth room 3 days after emergence on June 14, 2000. All cultivars were placed in 3 temperature regimens: 25/15, 30/20 and 30/25°C day/night temperatures. After thinning to one plant per pot on June 28, 2000, all plants of each cultivar were blocked into 5 replications based on their uniformity of establishment.

The experimental growth period was 6 weeks and the plants were harvested on July 28, 2000. Plant height and tiller numbers were recorded weekly and at 6 weeks the top was cut at ground level for measurement of leaf area and leaf number. Plants were separated into leaf and stem and then dried at 70°C for 72 h. Dry matter yields were recorded. The dried samples of each component for the 5 replications were bulked and ground in preparation for nitrogen analysis using near infrared spectroscopy (NIRS 6500). The concentrations of zinc (Zn), manganese (Mn), cobalt (Co) and copper (Cu) were determined by atomic absorption and of iodine (I) by spectrophotometery.

Field experiment

The experiment was conducted on a sandy clay-loam soil at the Suwanvajokkasikits Research Station, Pakchong, 150 km north-east of Bangkok. Soil of the experimental area was classified as a moderate reddish-brown laterite with pH 6.5. The chemical content of the soil in the top 0–15 cm was 60 ppm available P (Bray II), 110 ppm K and 2.0% organic matter. A randomised block design with 4 cultivar treatments and 4 replications was used. The plot size was 3 m × 5 m. The cultivars were those used in the controlled-environment study in Japan except for Natsukomaki, as seed was not available.

The area was ploughed and cultivated to produce a good seedbed before planting on December 10, 2000. All cultivars were raised in small pots prior to transplanting into the experimental area when the plants were 3 weeks old. Plants were planted in rows 50 cm apart with 50 cm between plants within the rows. A basal fertiliser dressing of N : P : K (15:15:15) at the rate of 300 kg/ha was applied at sowing. The area was irrigated once a week.

Grass dry matter yields were measured by cutting 2 quadrats (1.0 m × 1.0 m) with hand shears to 5 cm in each plot on March 10, 2001 (3 months after transplanting). The fresh material from these quadrats was dried at 80°C for 2 days and dry matter yield estimated.

Statistical analysis

In the controlled-environment room experiment, a randomised block design was used for each temperature regimen. For comparison among temperature regimens, a simple split-plot design was used with room temperature as the main plot and guinea cultivars as the sub-plots. For the field trial, a randomised block design was also adopted. Differences between species were tested at $P<0.05$. No statistical analysis was made of the chemical components as all replications of each cultivar were bulked.

Results

Controlled environment

General observations. Natsukaze seed germinated 3 days after sowing followed by Natsuyataka and Natsukomaki which germinated 1 day later. Gatton and TD 58 cultivars were slow to germinate and took nearly 6 days.

Plant height. Cultivars grown at 30/20°C and 30/25°C reached similar heights over the 6-week experimental period and were noticeably taller than cultivars grown at the lower temperature of 25/15°C (Table 1). The differences between cultivars were slight but there was a tendency for Natsukaze to be the top performer at the low temperatures, and Natsuyataka and Gatton to be best at the higher temperatures.

Tiller numbers. There were no differences between cultivars in terms of tiller number for any of the temperature regimens (Table 2). However, under the lowest temperature regimens, tillering was initially delayed and increased rapidly during the last week of the experiment. By comparison, both higher temperature regimens initiated tillering earlier but showed only a slight increase in tiller number beyond Week 4.

Leaf number and leaf area. There were very limited differences in leaf numbers between cultivars at the different temperatures although cv.

Natsukomaki tended to produce most leaves under all temperature regimens (Table 3).

The weekly rate of increase in leaf numbers was also initially slower at the low temperature compared with the two higher temperature treatments, but all temperature treatments produced similar leaf numbers at 6 weeks.

In terms of leaf area, however, all cultivars grown under the two higher temperature regimens reached similar leaf areas which were higher than those for cultivars grown under the lower temperature regimen (Table 4). At the low temperature of 25/15°C, Natsukaze produced significantly more leaf area than TD 58, Gatton and Natsuyataka.

Table 1. Effect of temperature on plant height at 1–6 weeks after emergence.

Temperature (day/night)	Cultivar	Plant height Weeks after seedling emergence					
		1	2	3	4	5	6
(°C)		(cm)					
25/15	TD58	4.4 b[1]	11.0 b	21.8	32.2	51.2 b	65.6
	Gatton	4.0 b	10.2 b	19.8	28.6	51.8 b	64.0
	Natsukaze	6.8 a	14.8 a	22.8	40.0	64.4 a	77.6
	Natsuyataka	4.6 b	12.0 b	21.8	30.0	41.2 b	61.8
	Natsukomaki	4.4 b	12.6 ab	20.2	30.6	49.6 b	56.4
	Mean	4.8 B	12.1 B	21.3 B	32.3 B	51.6 B	65.1 B
30/20	TD58	9.8 a	34.0	50.0	75.0 b	107.4	124.0 b
	Gatton	6.4 b	26.0	43.0	75.6 b	119.4	139.8 a
	Natsukaze	11.8 a	37.0	57.4	80.8 ab	101.0	117.6 b
	Natsuyataka	9.6 a	32.6	51.8	91.2 a	120.8	144.4 a
	Natsukomaki	8.8 ab	31.4	47.6	75.0 b	116.4	141.6 ab
	Mean	9.3 A	32.2 A	50.0 A	79.5 A	113.0 A	133.5 A
30/25	TD58	10.4 b	35.2 ab	51.2 b	72.8 b	107.0	115.6
	Gatton	8.2 b	26.2 b	48.4 b	80.4 a	114.4	136.4
	Natsukaze	15.4 a	36.4 a	61.2 a	81.8 a	105.4	119.4
	Natsuyataka	8.0 b	28.4 b	49.6 b	84.4 a	114.4	134.2
	Natsukomaki	9.8 b	29.0 b	43.0 b	71.6 b	109.0	127.8
	Mean	10.4 A	31.0 A	50.1 A	78.2 A	110.1 A	126.7 A

[1] Within columns for each and between temperature regimens, values followed by different lower and upper case letters, respectively, are significantly different (P<0.05).

Table 2. Effect of temperature on tiller number of guinea grass cultivars at 2–6 weeks after emergence.

Temperature (day/night)	Cultivar	Tiller number/plant Weeks after seedling emergence				
		2	3	4	5	6
(°C)						
25/15	TD58	0.0	0.2	2.8	4.2	12.8
	Gatton	0.0	0.0	2.2	4.8	13.0
	Natsukaze	0.0	0.2	2.4	5.2	11.4
	Natsuyataka	0.0	0.2	3.2	5.0	12.0
	Natsukomaki	0.0	0.8	2.8	7.2	14.4
	Mean	0.0	0.3 B	2.7 B	5.3 B	12.7 A
30/20	TD58	0.0	2.8 b[1]	7.4	7.4	8.4
	Gatton	0.0	3.0 b	6.6	7.6	8.0
	Natsukaze	0.0	3.4 b	7.4	7.4	8.8
	Natsuyataka	0.2	3.2 b	7.8	8.0	9.8
	Natsukomaki	0.6	5.4 a	9.4	10.2	10.8
	Mean	0.2	3.6 A	7.7 A	8.1 A	9.2 B
30/25	TD58	0.0	3.4	9.0	8.4	9.8
	Gatton	0.0	2.4	7.0	6.8	8.2
	Natsukaze	0.2	4.0	7.8	7.4	8.8
	Natsuyataka	0.2	4.4	8.2	8.4	8.4
	Natsukomaki	0.2	3.8	9.8	9.0	9.8
	Mean	0.1	3.6 A	8.4 A	8.0 A	9.0 B

[1] Within columns for each and between temperature regimens, values followed by different lower and upper case letters, respectively, are significantly different (P<0.05).

However, at the higher temperatures (30/20°C and 30/25°C), all cultivars, apart from Gatton, showed similar leaf areas which were significantly higher than at the low temperature (25/15°C).

Plant dry weight. Growth of leaf increased 2.5-fold and stem 5.5-fold as temperature increased from 25/15°C to 30/20°C with no further increase to 30/25°C (Table 4). At the higher temperature regimen, total plant weight for all cultivars was similar, but at the lowest temperature, Natsukaze produced more dry matter (P<0.05) than all cultivars except Natsukomaki.

Chemical composition. At the lowest temperature, all cultivars had much higher N, Zn, Mn and Cu

Table 3. Effect of temperature on leaf number of guinea grass cultivars.

Temperature (day/night)	Cultivar	Leaf number/plant Weeks after seedling emergence					
		1	2	3	4	5	6
(°C)							
25/15	TD 58	2.0	3.0 b[1]	4.6	12.4	19.4	40.6
	Gatton	2.0	3.0 b	4.2	10.5	19.5	46.5
	Natsukaze	2.0	3.0 b	4.8	11.4	20.2	35.6
	Natsuyataka	2.0	3.0 b	4.6	11.8	20.4	39.2
	Natsukomaki	2.0	3.6 a	5.6	13.4	28.4	51.4
	Mean	2.0 B	3.1 B	4.7 B	11.9B	21.6 B	42.7 A
30/20	TD58	2.8	4.6	9.8	30.6 b	38.2 b	43.0 ab
	Gatton	2.4	4.6	10.8	29.4 b	39.0 b	37.4 ab
	Natsukaze	3.0	4.8	10.8	28.6 b	35.4 b	31.6 b
	Natsuyataka	2.6	4.4	11.2	28.4 b	44.0 ab	47.8 a
	Natsukomaki	2.8	5.8	16.4	44.8 a	51.0 a	47.8 a
	Mean	2.7 A	4.8 A	11.8 A	32.4 A	41.5 A	41.5 A
30/25	TD58	3.0	5.2	10.2	35.6	47.8 b	49.0
	Gatton	3.0	5.0	11.4	35.6	41.2 b	38.0
	Natsukaze	3.0	5.6	13.6	34.8	37.8 b	36.2
	Natsuyataka	2.8	5.2	11.4	37.6	47.4 b	41.6
	Natsukomaki	3.0	6.0	14.6	45.0	62.0 a	52.8
	Mean	3.0 A	5.4 A	12.2 A	37.7 A	47.2 A	43.5 A

[1] Within columns for each and between temperature regimens, means followed by different lower and upper case letters, respectively, are significantly different (P<0.05).

Table 4. Effect of temperature on leaf area and total plant dry weight of guinea grass cultivars at the end of the experiment (6 weeks after transplanting).

Temperature (day/night)	Cultivar	Leaf area	Dry weight			Relative yield
			Leaf	Stem	Total	
(°C)		(cm^2/pot)		(g/plant)		(%)
25/15	TD58	542 bc[1]	1.80 b	1.13 b	2.93 b	14.7
	Gatton	574 bc	1.80 b	1.13 b	2.93 b	14.7
	Natsukaze	969 a	3.86 a	2.43 a	6.29 a	31.6
	Natsuyataka	449 c	1.48 b	0.95 b	2.43 b	12.2
	Natsukomaki	807 ab	2.75 ab	1.78 ab	4.53 ab	22.8
	Mean	668 B	2.34 B	1.48 B	3.82 B	19.2
30/20	TD58	2248 a	8.90 ab	6.81 b	15.71	79.1
	Gatton	1748 b	6.52 b	10.99 a	17.52	88.2
	Natsukaze	2272 a	10.21 a	9.59 ab	19.80	99.6
	Natsuyataka	2281 a	9.11 ab	9.42 ab	18.53	93.3
	Natsukomaki	2125 a	7.23 b	11.40 a	18.64	93.8
	Mean	2135 A	8.39 A	9.64 A	18.04 A	90.8
30/25	TD58	2624 a	9.79 a	7.38 c	17.16	86.4
	Gatton	2060 b	6.61 b	10.44 ab	17.05	85.8
	Natsukaze	2671 a	9.60 a	10.27 ab	19.87	100.0
	Natsuyataka	2441 a	8.31 ab	8.68 bc	17.00	85.6
	Natsukomaki	2452 a	7.04 b	11.43 a	18.47	93.0
	Mean	2450 A	8.27 A	9.64 A	17.91 A	90.2

[1] Within columns for each and between temperature regimens, means followed by different lower and upper case letters, respectively, are significantly different (P<0.05).

concentrations than at the higher temperatures while I and Co levels were variable (Table 5). The differences in mineral concentrations between cultivars were much greater at the lowest temperature than at the higher temperatures. Gatton and Natsuyataka contained noticeably more Zn, Mn and Cu than the other species at 25/15°C but at the higher temperatures, the only notable result was the appreciably lower Co concentrations in cultivar TD 58.

Field trial

Temperature during the experiment was cool with minimum temperature falling as low as 11.9°C which was lower than the minimum temperature in the control room in Japan (Table 6). Minimum temperatures of this magnitude are common during the dry cool season (November–February) in various regions of the central plain of Thailand where dairy farms are situated (Table 6).

In terms of the cultivars compared, Natsukaze grew rapidly and, at 3 months after transplanting, produced the highest dry matter yield ($P < 0.05$), with no difference between the other cultivars (Table 7).

Discussion

This study has demonstrated the variation in production potential of the range of cultivars tested, especially at low temperatures. While growth of all cultivars was markedly depressed in the controlled-environment study at the lowest temperature regimen (25/15°C), cultivars Natsukaze and Natsukomaki were much more productive in this situation than the remaining cultivars. The relative yield of these cultivars was 23–32% of the maximum yield under higher temperatures as compared with 12–15% for TD58, Gatton and Natsuyataka. It is significant that yields were similar for all cultivars at both of the higher temperature regimens tested.

Under the lowest temperature regimen, plant morphological characteristics were altered. Plants

Table 5. Effect of temperature on chemical composition of guinea grass cultivars (dry weight basis).

Temperature (day/night)	Cultivar	Chemical composition					
		N	Zn	Mn	I	Co	Cu
(°C)		(%)			(ppm)		
25/15	TD58	3.30	42.4	41.2	0.19	2.81	16.65
	Gatton	3.25	91.7	49.2	0.43	3.13	42.53
	Natsukaze	2.19	44.5	26.8	0.34	3.06	10.50
	Natsuyataka	3.78	61.3	59.0	0.31	11.00	25.12
	Natsukomaki	3.02	53.3	34.8	0.38	2.19	10.83
	Mean	3.11	58.6	42.2	0.33	4.44	21.13
30/20	TD58	1.06	15.3	35.7	0.35	0.54	8.01
	Gatton	1.04	26.3	26.3	0.29	1.43	7.91
	Natsukaze	0.69	18.5	19.5	0.23	6.70	9.29
	Natsuyataka	1.02	18.7	22.1	0.20	1.28	5.69
	Natsukomaki	0.80	21.6	26.2	0.26	1.62	6.22
	Mean	0.92	20.1	26.0	0.23	2.31	7.42
30/25	TD58	0.96	20.1	28.9	0.28	0.55	7.16
	Gatton	1.07	30.4	40.3	0.39	1.94	7.36
	Natsukaze	0.66	24.6	34.3	0.32	6.50	8.56
	Natsuyataka	1.10	24.4	33.3	0.36	2.35	8.25
	Natsukomaki	0.80	24.6	30.3	0.33	2.99	10.38
	Mean	0.92	24.8	33.4	0.33	2.87	8.34

Table 6. The mean minimum temperature (°C) during November–February (2000–2001) for various areas where dairy farms are situated.

Location	Months			
	Nov	Dec	Jan	Feb
Suwanvajokkasikit	18.6 (11.9–22.9)[1]	19.8 (14.1–22.0)	19.0 (15.0–23.1)	19.6 (16.8–23.4)
Muaklek	17.1	18.4	18.4	18.5
Ratchaburi	18.1	16.8	18.1	17.1
Kanjanaburi	16.3	17.1	18.1	19.1

[1] Range of minimum temperature.

had smaller leaves and hence total leaf area and were shorter than those grown at higher temperatures. While tillering was delayed at low temperatures, final tiller numbers were higher than for the high temperature treatments at 6 weeks as reported by Ivory (1975) in Ruzi grass (*Brachiaria ruziziensis*). This may be due to the balance of carbohydrate reserves with photosynthate production at low temperatures being surplus to growth and hence used to stimulate tillering. As reported by Whiteman (1968), Mannetje and Pritchard (1974) and Whiteman *et al*. (1984), plant size and leaf area in all cultivars were greater when temperature was increased.

Table 7. Dry matter yield of 4 guinea grass cultivars under field conditions in Thailand.

Cultivar	Dry matter yield
	(t/ha)
TD 58	1.50 b[1]
Gatton	1.20 b
Natsukaze	2.50 a
Natsuyataka	1.25 b

[1] Values not followed by the same letter differ at $P < 0.05$.

Above a temperature of 30/20°C plant responses in terms of plant height, leaf number and area and plant dry weight tended to flatten out which is in agreement with the finding of Ludlow and Wilson (1970). The optimum temperature for growth of *Panicum maximum* cv. Hamil is around 38°C (Ludlow and Wilson 1971). Since our maximum temperature in the controlled-environment study was only 30°C, the possibility exists that the low night temperatures of 25°C in our study may have limited the responses obtained at the highest temperature regimen (30/25°C).

The superiority of Natsukaze at lower temperatures was confirmed by the field study where Natsukaze significantly outyielded the other cultivars. This better adaptation of Natsukaze to lower temperatures may be a function of greater tissue expansion which is reflected in greater plant height and leaf area development. The paramount importance of leaf area to productivity has been emphasised by Watson (1947).

The higher concentrations of nutrients in plant material grown at lower temperatures possibly reflects the higher nutrient concentrations under restricted growth. It is significant that cultivars Natsukaze and Natsukomaki which produced the highest yields also had the lowest N levels. Concentrations of nutrients recorded in plant material grown under higher temperature regimens were considered inadequate for satisfactory dairy or beef production. Nitrogen concentrations were less than 1% in material which was only 42 days old. The mineral concentrations can be compared with those reported by Vijchulata *et al*. (1994) for 3–9-week regrowth in Thailand of 82–181 ppm Mn, 25 ppm Zn and 1.6–2.3 ppm Cu. The Co levels in our study (0.54–6.7 ppm) were significantly higher than the 0.16 ppm reported by Minson (1990) as a mean for tropical grasses.

The mean minimum temperature during the cool dry season in Thailand frequently falls to 18.6°C at Suwanvajokkasikit, 16.3°C at Kanjanaburi, 16.8°C at Ratchaburi and 17.1°C at Muaklek where most dairy farms are situated. Our findings suggest that Natsukaze is capable of producing acceptable dry matter yields of relatively high quality during this cool period provided that soil moisture is adequate for germination and growth. Hence, growing this cultivar as a special-purpose pasture on an appropriate proportion of the farm should help to reduce the feed shortage which normally occurs in November–February. Since it also grows as well as other cultivars at higher temperatures, it could also be used throughout the year. However, some degree of caution must be exercised as the cultivar Natsukaze was introduced into Thailand only recently and we know little of its performance and persistence under practical farming conditions.

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