Shade tolerance of selected hybrid napier cultivars under rainfed conditions

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Abstract

A field experiment was conducted for two years during 2013 and 2014 at the Agronomy Research Farm of Kerala Agricultural University, Thrissur to assess the shade tolerance potential of six selected cultivars of hybrid napier (Co-3, Co-4, Suguna, IGFRI-3, DHN-6 and PTH).The cultivars were exposed under full sunlight (open), 25 per cent and 50 per cent shade. The highest fresh and dry fodder yield was recorded under open condition. Among the cultivars, 'Suguna' was superior in fresh fodder yield in both years of study (100.54 Mg ha^{-1} in first year and 137.51 Mg ha^{-1} in second year) followed by 'Co-3' (94.46 Mg ha^{-1} and 131.51 Mg ha^{-1}). However, the performance of 'Suguna' and 'Co-3' were comparable under 25 per cent and 50 per cent shade. Number of tillers and leaves declined with increasing shade. Among the cultivars studied, as 'Co-3', 'Suguna' and 'IGFRI-3' recorded less than 15 per cent yield reduction under 25 per cent shade, they can be grown under tree crops with similar shade levels. Similarly, as the cultivars 'Co-3' and 'Suguna' recorded less than 25 per cent yield reduction under 50 per cent shade, they can be grown in plantations where the light availability is not less than 50 per cent.

Key words: Hybrid napier, Rainfed situation, Shade tolerance

Introduction

Hybrid napier is a popular fodder grass among small farmers of Kerala because of its high yielding potential and nutritive quality. With the advent of high yielding cultivars such as 'Co-3' and 'Co-4', which can yield fresh fodder in the range of 300-400 Mg ha^{-1} per year, its diffusion and spread among dairy farmers have increased in the recent years. However, most of these cultivars express their superior yield potential when grown under open conditions with irrigation. This limitation hinders its cultivation among resource poor farmers who do not have much open space for fodder cultivation. Lack of irrigation facilities is another problem. However, in Kerala, which enjoys typical humid tropical climate with plenty of rainfall, the spaces available under tree crops such as coconut can be utilized for fodder production, if shade tolerant and drought tolerant cultivars are identified.

Hybrid napier or bajra-napier hybrid is the F1 hybrid between bajra (*Pennisetum glaucum* (L.) R.Br.) and napier grass (*Pennisetum purpureum* Schum.). Antony and Thomas (2014) reported that hybrid napier cultivars such as 'Co-3', 'Co-4', 'Suguna' and 'PTH' can be recommended for rainfed conditions as they survived summer drought periods. 'Co-3' and 'Co-4' are cultivars released from Tamil Nadu Agricultural University and 'Suguna' from Kerala Agricultural University. 'IGFRI-3' is a shade tolerant cultivar recommended for intercropping (Sunil Kumar et al., 2012). 'DHN-6', the cultivar released from IGFRI regional station, Dharward, is superior in terms of yield (Pandey and Roy, 2011); however, its adaptation to shade is not known. 'PTH' (*Pennisetum* trispecific hybrid), a cross between three species of *Pennisetum* (*P. glaucum* X *P. purpureum* X *P. squamulatum*) obtained from IGFRI regional station, Dharwad was also included in the study as it is generally recommended for rainfed conditions (Biradar et al., 2008). 'PTH' acquired softness from bajra, high yield potential from napier grass and drought tolerance from *P. squamulatum*.

Shade level is the most important factor determining yield of pastures grown in plantations (Shelton et al., 1987). Low light intensity affects forage quality of grasses (Wilson and Wong, 1982) and severe reduction in light will reduce photosynthetic productivity and

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growth of plants (Monteith et al., 1991).The extent of growth reduction depends on the amount of shade and degree of shade adaptation (Terashima and Hikosaka, 1995). According to Singh et al. (1995), growth parameters like leaf number, leaf length, leaf width, and number of tillers are closely related to yield; hence, any change in these parameters would be reflected in yield too. Plants grown under shade try to adjust to low light levels by various mechanisms such as increased plant height, leaf length, and leaf width; and reduced number of tillers and leaves in order to attain better access to sunlight. In the circumstances, the best option is to grow specific cultivars tolerant to shade. In the case of hybrid napier, there is a genuine demand for high yielding cultivars that can be introduced in tree crop based farming systems with limited water supply. Hence, a study was conducted with selected cultivars maintained under rainfed conditions.

Materials and Methods

A field experiment was conducted for two years during 2013 and 2014 at the Agronomy Research Farm of Kerala Agricultural University, Thrissur. The soil of the experiment site is sandy clay loam (Order:Utisol). The amount of rain fall received during the crop growth period is given in Fig. 3. The highest amount of rain fall was received during the month of July during south west monsoon and in the month of October during north east monsoon in both the years. The experiment was laid out in split plot design with three main plot and six sub plot treatments, replicated thrice, adopting the recommended package of practices of Kerala Agricultural University (KAU, 2011). Full sunlight (open), 25 per cent and 50 per cent shade levels constituted the main plot treatments and the sub plot treatments consisted of six selected cultivars of hybrid napier ('Co-3', 'Co-4', 'Suguna', 'IGFRI-3', 'DHN-6' and 'PTH'). Shade levels were established using synthetic green shade nets of 25 per cent and 50 per cent by raising wooden poles at 3.0 m above ground level. Rooted slips were planted in each plot of 12.96 m^2 (3.6m x 3.6m) at a spacing of 60 cm x 60 cm on 03 July 2013 with the onset of south west monsoon and the crop was maintained as a perennial crop for two years. Farm yard manure at 25 Mg ha^{-1}, as well as P_2O_5 and K_2O at 50 kg ha^{-1} each were applied at the time of land preparation. Nitrogen at 200 kg ha^{-1} was applied in three splits as basal and after the first and second harvests for the first year. During the second year, the recommended full dose of farm yard manure, P_2O_5, K_2O and one third dose of nitrogen were applied after the first harvest, and the remaining nitrogen was applied in two splits after the second and third harvests. The first harvest was taken at 75 days after planting and the subsequent harvests at 45 days intervals. There were four harvests during the first year and five in the second year; but no harvesting was done during summer seasons because of non receipt of rainfall.

Fresh fodder yield from each plot was recorded immediately after cutting and expressed in Mg/ha. Dry weight was recorded by randomly selecting five plants from each plot and by drying them at 80 ± 5 ºC for 24 hours until constant weight was achieved. From this value, dry fodder yield in Mg/ha was calculated. Plant height, leaf length, leaf width, number of tillers per clump and number of leaves per clump were recorded just before each harvest to assess the phenotypic response of crop to varying light intensities. The mean data of various parameters were calculated based on four and five observations for the first and the second year respectively as there were four harvests in the first year and five harvests in the second year. The relative percentage reduction for 25 percent shade was worked out taking open condition as base level and that of 50 percent shade was worked out taking open condition and 25 percent shade level as base levels.

Results and Discussion

Shade levels significantly affected fodder production and growth parameters of hybrid napier. In both years, increasing shade level had a facilitating effect on plant height, leaf length and leaf width (Table 1). Plants showed maximum plant height, leaf length and leaf width under 50 per cent shade. As shading stimulates the synthesis of auxin and gibberellins, plants show shade avoidance syndromes such as increased plant height and etiolated leaves, because these hormones promotes cell division, cell elongation, apical dominance and inter nodal elongation (Keuskamp et al., 2010). In the present experiment, plants showed an increase in plant height of 10-15cm for every 25 per cent increase in shade level.

The results showed strong interaction with cultivars and shade levels. Among the cultivars, 'Suguna' recorded the maximum height at all the shade levels. Under open conditions (full sunlight), for 'Suguna', the mean plant heights were 124.92 cm and 143.94 cm in the first and second year respectively. In plots with 50 per cent shade

Table 1. Plant height, leaf length, and leaf width of hybrid napier cultivars under different shade levels

Treatment	Mean plant height (cm)		Mean leaf length (cm)		Mean leaf width (cm)	
	First year	Second year	First year	Second year	First year	Second year
Shade levels						
0	117.53	134.91	60.33	76.15	1.57	1.95
25	132.22	152.43	69.41	89.27	1.76	2.20
50	142.85	163.50	76.18	96.57	1.91	2.46
LSD 5%	0.70	0.968	0.77	1.67	0.01	0.02
Cultivars						
Co 3	133.80	154.55	75.07	94.79	1.96	2.41
Co 4	133.53	152.86	73.30	93.35	2.05	2.46
SugunaI	137.54	158.20	77.85	96.22	1.95	2.48
GFRI 3	113.92	136.12	57.64	77.24	1.54	2.13
DHN 6	133.42	157.57	74.18	94.96	2.23	2.78
PTH	133.01	142.38	53.78	67.39	0.75	0.97
LSD 5%	1.01	0.859	1.37	1.98	0.05	0.04
Open						
Co 3	117.68	138.50	66.30	82.53	1.73	2.15
Co 4	119.79	138.75	64.13	82.59	1.94	2.20
SugunaI	124.92	143.94	66.17	80.76	1.70	2.19
GFRI 3	103.04	117.93	49.90	70.38	1.41	1.92
DHN 6	119.53	140.56	69.95	82.44	2.07	2.45
PTH	120.24	129.79	45.53	58.17	0.58	0.82
25 % shade						
Co 3	135.75	157.82	75.30	95.96	2.02	2.40
Co 4	134.27	153.53	73.58	95.64	2.07	2.44
SugunaI	137.03	160.04	79.30	100.43	1.97	2.49
GFRI 3	114.88	138.71	59.18	78.10	1.53	2.14
DHN 6	136.12	160.40	74.33	98.12	2.25	2.76
PTH	135.30	144.07	54.78	67.35	0.75	0.98
50 % shade						
Co 3	147.97	167.32	83.63	105.88	2.14	2.67
Co 4	146.53	166.29	82.18	101.81	2.14	2.75
SugunaI	150.68	170.61	88.10	107.47	2.18	2.75
GFRI 3	123.85	151.72	63.85	83.24	1.69	2.33
DHN 6	144.60	171.74	78.25	104.33	2.38	3.13
PTH	143.49	153.30	61.05	76.65	0.92	1.11
LSD 5%	1.74	1.476	2.38	3.41	0.08	0.08

levels, for 'Suguna', the mean plant heights were150.68 cm and 170.61 cm during the first and second year. Under 25 per cent shade, 'Suguna', 'DHN-6', 'PTH', and 'Co-3' were on par during the first year, whereas in the second year, 'Suguna' and 'DHN-6' were on par.

Leaf length and leaf width decide the leaf size of the plant, and leaf size is an indication of the photosynthetic area of plants which is determined by the number and size of cells of which the leaf is built and influenced by light, moisture regime and supply of nutrients (Arnon, 1975). For every 25 per cent increase in shade level, plants showed an increase in leaf length of 10-20 cm. Over the two years, maximum leaf length was attained by 'Suguna' followed by 'Co-3' and 'DHN-6', which were on par. According to Reynolds (1995), reduced light diminishes the capacity of plants to accumulate carbohydrates and plants try to adjust to low light levels through various mechanisms such as reduced rate of respiration and increased leaf area. These changes

improve the competitive ability of plants and thus help to reduce the respiratory load. As per Table 1, under 50 per cent shade, 'Suguna' recorded maximum mean leaf length of 88.10 cm and 107.47 cm in the first and second year. Leaf width showed an increase of 0.15-0.25 cm for every 25 per cent increase in shade level. Over the two years, the cultivar 'DHN-6' recorded maximum mean leaf width of 2.38 cm and 3.13 cm in the first and second year under 50 per cent shade.

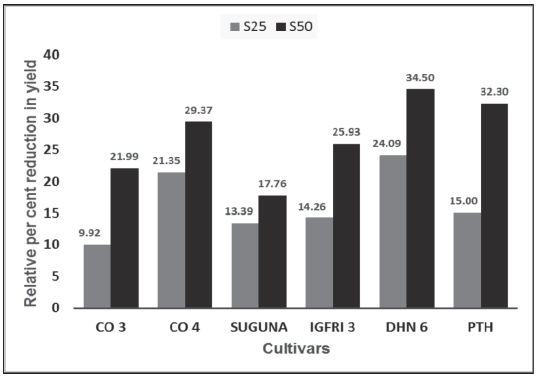

Figure 1. Relative reduction in yield of hybrid napier cultivars under different shade levels

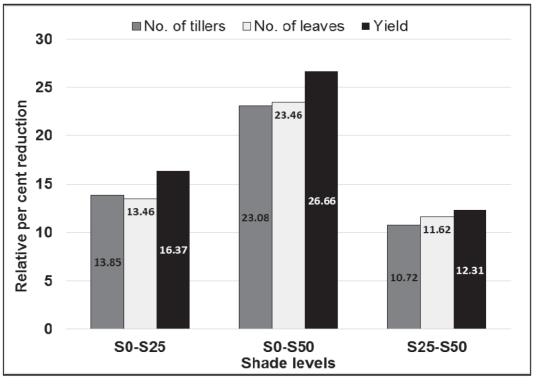

Figure 2. Relative reduction in yield, no. of tillers and no. of leaves of hybrid napier cultivars under different shade levels

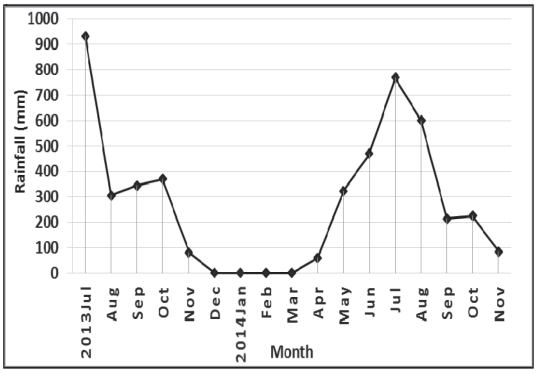

Figure 3. Total monthly rainfall during the crop period at Vellanikkara, Thrissur

The results indicate that in hybrid napier, increasing shade levels has a negative effect on tiller production and the rate of tillering varies between cultivars. The control of tillering in grasses is the contribution of genetic and physiological factors and their interaction with environmental factors (Assuero and Tognetti, 2010). In the present experiment, the relative percentage reduction in number of tillers was 10 for every 25 per cent increase in shade level (Fig.2). Gautier et al. (1999) observed that shading reduced tillering by delaying the development of tiller buds into tillers. The mean number of tillers was maximum for 'PTH' (39.78 and 65.53 in the first and second year) followed by 'IGFRI 3' (37.03 and 53.02 in the first and second year) under full sunlight compared to shaded condition (Table 2). Under shaded conditions, maximum number of tillers was observed in 'PTH' followed by 'IGFRI 3'.The least number of tillers was recorded by 'DHN-6' under varying shade levels throughout the experiment.

The rate of leaf production depends on the number of tillers produced, and hence the number of leaves produced followed the same trend as that of tiller number. The maximum number of leaves was produced under full sunlight compared to shaded conditions. According to Gautier et al. (1999) shading delayed phyllochron in plants, which in turn, decreases the rate of leaf development. Relative percentage reduction in number of leaves was 10 for every 25 per cent increase in shade level (Fig.2). As presented in Table 2, the mean number of leaves was maximum for 'PTH' (226.87 and 423.66 in the first and second year respectively) followed by 'IGFRI3' (222.59 and 363.76 in the first and second year respectively) under full sunlight compared to shaded condition.

Fodder yield was significantly reduced under shade (Table 2). As suggested by Senevirathna et al. (2003), reduction in solar radiation negatively affects photosynthetic productivity and carbohydrate assimilation. Negative effects of shade on fodder yield of hybrid napier under coconut was reported by Pandey et al. (2011). Among the cultivars, 'Suguna' was superior in fodder yield in both years of study followed by Co-3, and the lowest was in 'PTH'. As interaction was significant, the performance of cultivars under different

Table 2. Fresh and dry fodder yield, number of tillers clump^{-1}, and number of leaves clump^{-1} of hybrid napier cultivars under different shade levels

Treatment	Fresh fodder yield (Mg ha^{-1})		Dry fodder yield (Mg ha^{-1})		No. of tillers clump^{-1}		No. of leaves clump^{-1}	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
Shade levels								
0	90.32	142.91	15.88	25.05	31.05	45.12	179.87	305.98
25	77.96	115.68	13.75	20.36	25.98	39.99	150.51	273.55
50	68.34	101.48	12.08	17.91	23.12	35.82	130.16	246.97
LSD 5%	3.33	1.64	0.62	0.33	0.81	0.97	2.71	0.59
Cultivars								
Co 3	94.46	131.51	17.19	23.94	25.60	35.97	143.85	246.00
Co 4	70.67	124.66	14.14	24.93	22.20	33.18	121.35	230.94
SugunaI	100.54	137.51	18.90	25.85	26.45	37.35	156.30	258.20
GFRI 3	81.98	109.96	14.75	19.79	33.01	47.80	197.15	331.58
DHN 6	73.14	116.87	9.5	15.19	18.51	29.23	106.24	207.04
PTH	52.45	99.62	18.92	16.93	34.55	58.35	196.21	379.23
LSD 5%	2.26	3.20	0.40	0.59	0.78	0.54	2.41	1.40
Open								
Co 3	108.31	143.70	19.72	26.16	30.06	39.87	169.80	275.11
Co 4	80.34	159.39	16.07	31.88	27.27	37.35	148.78	256.54
SugunaI	111.34	154.62	20.93	29.06	31.13	41.80	182.46	285.24
GFRI 3	91.86	130.97	16.53	23.57	37.03	53.02	222.59	363.76
DHN 6	87.40	151.28	11.36	19.67	21.05	33.13	128.75	231.56
PTH	62.70	117.46	10.65	19.97	39.78	65.53	226.87	423.66
25 % shade								
Co 3	96.89	130.34	17.64	23.73	24.69	36.04	142.70	243.95
Co 4	70.04	111.75	14.01	22.34	21.04	33.24	114.69	230.36
SugunaI	97.15	132.92	18.26	24.99	26.11	36.87	157.55	258.52
GFRI 3	81.65	108.17	14.70	19.48	31.91	47.24	192.14	329.34
DHN 6	71.24	106.35	9.26	13.83	18.00	28.28	99.70	202.08
PTH	50.77	104.56	8.64	17.78	34.13	58.27	196.27	377.03
50 % shade								
Co 3	78.17	120.49	14.23	21.92	22.04	32.00	119.06	218.93
Co 4	61.64	102.85	12.32	20.57	18.30	28.93	100.57	205.93
SugunaI	93.14	124.98	17.52	23.50	22.11	33.37	128.87	230.83
GFRI 3	72.43	90.75	13.04	16.33	30.08	43.13	176.72	301.64
DHN 6	60.77	92.98	7.91	12.09	16.47	26.27	90.26	187.48
PTH	43.89	76.83	7.46	13.06	29.75	51.24	165.48	337.00
LSD 5%	3.93	5.55	0.69	1.01	1.35	0.95	4.18	2.42

shade levels was also considered. During the first year under full sunlight, 'Suguna' (111.34 Mg ha^{-1} yr^{-1}) and 'Co-3' (108.31 Mg ha^{-1} yr^{-1}) were on par. The same trend was also noticed under 25 per cent shade level.

In the second year, under full sunlight, 'Co-4' (159.39 Mg ha^{-1} yr^{-1}) and 'Suguna' (154.62 Mg ha^{-1} yr^{-1}) were almost similar in performance. Under 25 and 50 per cent shade levels, 'Suguna' compared equally well with Co-3, fresh fodder yield being 132.92 and 124.98 Mg ha^{-1} yr^{-1} for Suguna and 130.34 and 120.49 Mg ha^{-1} yr^{-1} for 'Co-3'.

The dry fodder yield followed the same trend as that of fresh fodder yield while considering the effect of cultivars alone. However, under full sunlight, in the first year,

the highest yield was recorded by 'Suguna' (20.93 Mg ha^{-1} yr^{-1}) followed by 'Co-3' (19.72 Mg ha^{-1} yr^{-1}). Under 25 and 50 per cent shade, 'Suguna' recorded the highest dry fodder yield of 18.26 and 17.52 Mg ha^{-1} respectively followed by 'Co-3'. During the second year, under full sunlight, 'Co-4' recorded the highest dry fodder yield (31.88 Mg ha^{-1}) followed by 'Suguna' (29.06 Mg ha^{-1}). Under 25 and 50 per cent shade, 'Suguna' recorded the highest dry fodder yield of 24.99 Mg ha^{-1} and 23.50 Mg ha^{-1} respectively followed by 'Co-3'.

The trend in yield reduction observed under shaded situation can be explained by the data on relative reduction in tiller number and leaf number with increasing shade levels (Table 2 and Fig. 2). The rate of fodder production is a function of tiller production and leaf growth (Selvi and Subramanian, 1993). The relative percentage reduction in number of leaves was directly related to the relative percentage reduction in number of tillers (Fig. 2). The average relative percentage reduction in number of leaves with respect to open condition was 13.46 and 23.46 with corresponding values of 13.85 and 23.08 in the relative percentage reduction of tillers, as the shade levels were raised to 25 per cent and 50 per cent respectively. The relative percent reduction in number of leaves for 50 per cent shade level when viewed with a base shade level of 25 per cent was 11.62 with a corresponding value of 10.72 in the relative per cent reduction of tillers. This trend was also reflected in relative percentage reduction of yield as 16.37 and 26.66 when the shade levels were raised to 25 and 50 per cent respectively. The relative percentage reduction in yield for 50 per cent shade level when viewed with a base shade level of 25 per cent was 12.31. Pandey et al. (2011) observed that in grasses, total reduction in yield was in the range of 18-75 percent for a corresponding reduction in light from 32 to 59 per cent.

In general, percentage reduction in fodder yield was approximately 10 for every 25 per cent reduction in light intensity. Relative percentage reduction in yield depends on cultivars too (Fig.1). Among the cultivars studied, 'Co-3'(9.92 %), 'Suguna'(13.39%) and 'IGFRI-3'(14.26%) recorded less than 15 per cent yield reduction under 25 per cent shade, and hence, they can be grown under tree crops with similar shade levels. As the cultivars 'Co-3' and 'Suguna' recorded less than 25 per cent reduction in total yield under 50 per cent shade, they can be grown in plantations where the light availability is not less than 50 per cent. These findings have implications for Kerala where tree crops predominate the cropping pattern. In Kerala, in 2013-14, out of 20.51 lakh ha of net area sown, 8.09 lakh ha was under coconuts (GOI, 2015). On an average, up to 70 per cent solar radiation is available for inter crops in coconut gardens (Reynolds, 1995), which can be utilized for growing fodder crops such as hybrid napier. The results thus indicate that the cultivars 'Suguna', 'Co-3', and 'IGFRI-3' are suitable for growing under reduced light intensities.

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