FEED VALUE OF BLUE PANIC (*Panicum antidotale* retz.) GRASS AT DIFFERENT GROWTH STAGES AND UNDER VARYING LEVELS OF HUMIC ACID IN SALINE CONDITIONS

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ABSTRACT

This study underscored an underexploited crop, blue panic grass as a potential crop for hot and saline regions. It investigated feed value of the crop at two growth stages, before flowering (BF) and after flowering (AF), and under different levels of humic acid application (HA, at 0, 15, 30, 45, 60, 75, and 90 kg ha^{-1}). Significant (P < 0.05) effects of different growth stages, HA while non-significant effect of their interactions were observed for various parameters. Low dry matter (DM) was recorded for cutting at BF than that for AF, whereas the DM production increased with increasing HA levels. For plants at BF stage, low acid detergent fiber (ADF) and low neutral detergent fiber (NDF) levels were observed. In contrast, leaf/stem ratio, digestible dry matter (DDM), crude protein (CP) content, and the concentrations of macro and micro elements, were all high in plants at BF stage. A similar pattern for all the above mentioned parameters was observed for augmentation of HA. The study suggests the application of 75-90 kg ha^{-1} HA to the soil, whereas cutting of the crop at BF stage for enhancing both the yield and quality of the crop. Furthermore, findings of this study are expected to be a valuable reference for researchers and producers, because it broadly highlights the grass feed values.

Key words: Crude protein, DDM, dry matter, forage, mineral composition, NDF

INTRODUCTION

Blue panic (*Panicum antidotale* Retz.) is an important perennial grass that has an immense potential for growing in stress condition (Jung et al., 1990; Zhang et al., 2012; Descheemaeker et al., 2014). However, due to the limited agronomic information about its potential for growing in saline condition, and forage value, it has not received much attention as a fodder crop, and is therefore, not grown widely across the world for forage purposes. Thus up until now, its' growth stage for cutting has not been established. This study explored the feed value of this grass, under saline conditions because it is supposed a good choice for growing under salt stress. Moreover, humic acid is widely believed to enhance crop growth under saline conditions—so we wanted to explore its add-on advantage in salt tolerance.

Previously, blue panic species have been investigated botanically or physiologically, for example for their water use efficiency (Shahbaz et al. 2011), for their morphology and anatomy (Hameed et al. 2012; Nawaz et al. 2013), and for their heat tolerance (Wasim et al. 2013). However, data regarding blue panic growth, yield, and feed value have been lacking so far. Crop growth and feed values are important considerations for adopting specific crop species as livestock forage (Long et al. 1999; Barry 2013, Geren and Kavut, 2015). Dong et al. (2013) and Geren (2014) underscored that for determining the feed value of a crop, plant height, leaf/stem ratio, dry matter content, crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) are important parameters. In addition, Atis et al. (2015) reported that forage yield, composition, and quality are directly related to its harvesting time. Likewise, a humic acid have been reported to enhance nutrient availability, nutrient absorption, nutrient utilization, plant growth, physiology and metabolism through various mechanisms and is therefore believed to enhance crop yield under saline condition (Schiavon et al., 2010; Berbara & Garcia, 2014).

Based on previous research and the literature, this study focused on several parameters related to the growth, nutritional value, and the mineral composition of blue panic grass at the two different growth stages, under natural saline conditions. The natural saline conditions in this study represent predominant saline conditions around the world, so it is expected that the results to be relevant globally.

MATERIALS AND METHODS

Experimental details

A 2-years field experiment on growing blue panic was conducted at Hada A'Sham area of Jeddah, Saudi Arabia during 2011 & 2012. The average monthly temperature and precipitation for the site are presented in Table 1. Furthermore, the site initial soil properties and after completion of the experiment, for selected treatments is presented in Table 2. Blue panic seeds from Pacific Seed Company were used in the experiment. Each year the seeds were sown in the first week of January using row-to-row distance of 30 cm. A new section of the experimental field was used each year. The humic acid (HA) levels (0, 15, 30, 45, 60, 75, and 90 kg ha^{-1}) were applied to the soil in powder form, two weeks prior to sowing of the crop by incorporation in upper 15 cm soil layer, whereas the crop harvesting was managed at two growth stages, according to the experimental treatment. The experiment was conducted in a randomized complete block design with a split-plot arrangement (growth stages as the main plot factor and HA as a sub-plot factor). Each sub-plot size was 2 x 2.5 m^2. Plots allotted to BF (before flowering) stage were harvested just before flowering initiation, whereas plots allotted to AF (after flowering) stage were harvested after complete flowering. Saline borehole water of 4000 ppm was used for irrigating the crops. Just one time weeding was practiced—that was done manually 20 days after sowing. All other agronomic practices were carried out uniformly across all treatments.

Table 1. Mean monthly temperature (°C) and precipitation at experimental sites.

Weather Parameters	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Min. T °C (2011)	14.5	16.7	18.6	21.5	22.9	24.8	26.1	27.4	25.2	23.1	22.8	18.5
Min. T °C (2012)	15.5	18.1	18.4	21.4	23.5	25.0	26.3	27.5	25.4	22.9	23.0	19.0
Long term min. T °C	15.6	18.1	19.2	21.0	23.2	24.0	26.1	27.0	25.2	23.5	22.1	19.0
Max. T °C (2011)	28.0	29.1	29.5	33.0	35.1	36.4	37.0	37.5	35.8	35.0	30.1	28.1
Max. T °C (2012)	28.3	29.2	28.4	32.6	34.8	36.0	36.9	37.2	36.0	35.2	30.0	28.2
Long term max. T °C	28.1	29.0	30.4	32.8	35.0	36.0	37.1	37.5	36.2	35.0	39.8	28.1
2011 Rainfall (mm)	4.9	-	-	-	-	-	-	-	-	-	25.0	30.4
2012 Rainfall (mm)	4.4	3.08	-	-	-	-	-	-	-	1.12	12.2	10.0
Long term Rainfall (mm)	4.5	1.18	1.2	0.5	-	-	-	-	-	0.89	3.2	3.3

Table 2. Soil properties of the site (0-30 cm) initially and after completion of the experiment

Soil properties	Initial values	After completion of the experiment for selected treatments		
		0 HA ha^{-1}	**75 HA ha^{-1}**	**90 HA ha^{-1}**
pH	7.80	7.79	7.74	7.72
Organic matter (%)	1.86	0.81	1.21	1.22
CEC (cmol$_c$ kg^{-1})	13.21	13.21	16.11	16.11
EC (*dS/m*)	1.74	1.78	1.76	1.76
Soil texture	Loamy Sand	Loamy Sand	Loamy Sand	Loamy Sand
Total N (%)	0.11	0.10	0.12	0.12
Quantity (mg kg^{-1})				
P	48.7	49.2	46.0	46.4
K	304.1	288.5	344.3	352.6
Ca	4166	3452	4134	4222
Mg	234	122	247	252
S	154	122	118	116
Na	324	346	340	344
B	10.4	9.7	9.8	9.8
Mn	14.0	12.1	13.8	13.9
Fe	48.12	34.10	60.2	64.0
Co	4.5	4.3	4.4	4.4
Cu	1.61	1.20	1.48	1.55
Zn	2.86	1.11	3.12	3.11

Soil physical and chemical analysis

To determine soil properties, random soil samples were taken from the experimental field at a depth of 0-30 cm and were mixed as a composite sample to determine the initial soil properties. After completion of the experiment, similarly soil samples were collected from the control, as well as from the sub-plots with selected treatments of HA, for comparative analysis of various soil properties. Soil pH, texture, and electrical conductivity (EC) were determined following standard procedures

(Daur, 2014). The cation exchange capacity (CEC) was measured following the method of Page et al. (1982), and organic matter was determined using the Walkley-Black method (Nelson and Sommers, 1996). Nitrogen (N) content was quantified using a Perkin-Elmer CHNS/O Analyzer (Model 2400), following the manufacturer's instructions (PerkinElmer, Inc., USA). Phosphorus (P) was determined colorimetrically, following the protocol described by Ryan et al. (2001), whereas all other elements (K, Ca, Mg, S, Na, B, Mn, Fe, Co, Cu and Zn) were determined using Varian inductively coupled plasma-optical emission spectroscopy (ICP-OES) according to manufacturer's instructions.

Crop yield and feed value

To assess crop yield and the apparent quality, data on plant height, crop dry matter (DM), and leaf/stem ratio were compiled each year on the basis of 3 cuts. Each cut took on the average 35 days to BF stage and 45 days AF stage. During each cut the data was recorded following proper agronomic procedures as described earlier (Daur et al., 2011; Daur and Tatar, 2013). Dry matter yield was determined by oven-drying the samples at 65˚C for 48 hours, following procedure of Daur and Tatar (2013) with some modifications. Instead of drying the whole plants, they were separated into leaf and stem fractions to determine their respective dry matter and total DM per cut.

The crop feed value was evaluated based on the chemical composition, by analyzing the crop's dry matter samples from each sub-plot at all cuts—and then means per cut were workout. For the analysis of each cut, the oven dried plant samples were milled to 1 mm, and these samples were analyzed for crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents, as well as digestible dry matter (DDM), and mineral composition. Crude protein content was determined using the equation of N × 6.25, as described in AOAC method 2001.11 (AOAC, 2000). NDF and ADF for all samples were determined following the procedure of Van Soest et al. (1991), whereas DDM was calculated using the following equation (Mertens, 1987): DDM = 88.9 − 0.78 × ADF

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Statistical analysis

Statistical analyses of the data, and the calculation of the least significant differences (LSD) (P < 0.05) were conducted using SAS software.

RESULTS

Growth stage (GS) and humic acid (HA) levels significantly (P < 0.05) influenced plant height, DM, leaf/stem ratio, CP, NDF, ADF, and DDM, whereas their interaction (GS × HA) did not (Table 3). Statistically significant highest plant height (55.80 cm) and DM (7.80 tons ha^{-1}) were observed for 90 kg ha^{-1} HA application level at AF stage. In contrast lowest plant height (42.11 cm) and DM (6.16 tons ha^{-1}) were for BF stage in control plots. However, highest leaf/stem ratio of DM (1.72) was recorded for 90 kg ha^{-1} HA level at BF stage. For HA treatments, the corresponding LSD values indicate that these quantities at 90 kg HA ha^{-1} are statistically comparable to those observed at levels of 75 kg HA ha^{-1} or lower in their relevant growth stages. This indicates that HA application stimulates the crop growth at smaller HA doses, and that higher HA levels can increasingly boost the crop growth. Additionally, ranges with larger values for plant height (48.40 –55.80 cm) and total DM production per cut (6.55–7.80 tons ha^{-1}) were observed for AF stage compared to BF where plant height and DM production per cut ranged (42.11– 48.18 cm) and (6.16–6.98 tons ha^{-1}) respectively. However, leaf/stem ratio was with greater values (1.20–1.72) at BF stage compared to AF stage (1.00 – 1.40). Also, the ranges for CP (8.60–9.61%), NDF (54.00–58.81%), ADF (24.20–31.23%), and DDM (64.54–7.02%) were more desirable in terms of forage value at BF stage of the plant compared with AF stage. In the AF stage, the aforementioned ranges were as follows: CP (7.00–7.84%), NDF (58.80–72.24%), ADF (30.00–38.36%), and DDM (58.98–65.50%). In each of the relevant growth stages, there was no difference in results between adding 75 or 90 kg ha^{-1} of HA applications (P < 0.05), although compared with all the other HA applications levels, either one or both of these treatments were significantly more advantageous.

Likewise, analyses of macroelements indicated that N, P, K, and Mg contents (g kg^{-1} of DM) were significantly higher for plant in BF stage compared with AF (P < 0.05), and that there was no significant difference in Ca, S, and Na contents (Table 4). Likewise, N, P, K, and Mg contents increased significantly with increasing HA applications levels, although Ca, S, and Na were not influenced by HA levels. In addition, no significant interaction of GS and HA was found for any of the macroelements.

Analysis of microelements revealed that B, Mn, Fe, Cu, and Zn contents (mg kg^{-1} of DM) were significantly (P < 0.05) higher in plants at BF stage compared with AF (Table 5). In contrast, Co did not differ significantly between both growth stages. Across the levels of HA applications, B, Fe, Cu, and Zn contents (mg kg^{-1} of DM) significantly increased with higher HA levels while Mn and Co were non-significant. Finally, no significant interaction was observed between GS and HA for the studied microelements.

Table 3. Growth and feed value of blue panic at two different growth stages, and at various levels of HA applications.

Growth Stage (GS)	HA Level (Kg ha⁻¹)	PH (cm)	DM (tons ha⁻¹)	DM partitioning (%) Stem	DM partitioning (%) Leaf	CP (% DM)	NDF (% of DM)	ADF (% of DM)	DDM (% of DM)
Treatments					**Parameters**				
Before flowering (BF) stage									
	0	42.11	6.16	34.60	65.40	8.60	58.81	31.23	64.54
	15	42.20	6.16	35.44	64.56	8.75	58.32	30.97	64.74
	30	44.18	6.50	35.84	64.16	9.20	57.35	30.45	65.15
	45	45.90	6.73	36.00	64.00	9.56	56.14	29.81	65.65
	60	46.00	6.80	36.00	64.00	9.37	55.51	27.48	67.47
	75	46.50	6.82	35.20	64.80	9.60	55.16	26.10	68.54
	90	48.18	6.98	34.34	65.66	9.61	54.00	24.20	70.02
After flowering (AF) stage									
	0	48.40	6.55	44.12	55.88	7.00	72.24	38.36	58.98
	15	50.40	6.81	44.80	55.20	7.00	72.01	38.24	59.07
	30	52.12	7.19	46.12	53.88	7.32	70.81	37.60	59.57
	45	55.18	7.40	48.96	51.04	7.65	69.40	36.85	60.16
	60	55.00	7.32	49.00	51.00	7.50	69.31	34.80	61.76
	75	55.80	7.56	49.60	50.40	7.75	69.22	32.76	63.35
	90	55.80	7.80	50.12	49.88	7.84	66.80	30.00	65.50
LSD GS		2.55	0.32	2.04	2.15	0.53	4.01	2.13	4.11
LSD HA		3.01	1.20	2.86	3.53	0.36	4.00	3.10	2.54
Statistical significance:									
GS		*	*	*	*	*	*	*	*
HA		*	*	*	*	*	*	*	*
CS x HA		NS	NS	NS	NS	NS	NS	NS	NS

PH = Plant height; DM = Average Dry matter per cut; CP = Crude protein, NDF, Neutral detergent fiber; ADF = acid; detergent fiber; DDM = digestible dry matter

Table 4. Macro-elemental contents of blue panic at two different growth stages, and at various levels of HA applications.

Growth Stage (GS)	HA Level (Kg ha⁻¹)	N	P	K	Ca	Mg	S	Na
Treatments		**Macro-minerals (g kg⁻¹ DM)**						
Before flowering (BF) stage								
	0	14.33	2.30	21.90	3.90	2.31	2.22	2.20
	15	14.58	2.40	22.00	4.10	2.52	2.40	2.13
	30	15.34	2.40	22.42	4.50	2.40	2.30	2.10
	45	15.54	2.40	22.60	4.41	2.40	2.32	2.08
	60	15.63	2.60	22.80	4.90	2.48	2.36	2.04
	75	16.01	2.84	22.92	4.88	2.50	2.42	2.01
	90	16.02	2.90	23.11	4.91	2.53	2.43	2.00
After flowering (AF) stage								
	0	13.42	2.10	19.10	3.42	2.25	2.16	2.12
	15	13.87	2.16	20.21	4.12	2.30	2.20	2.12
	30	14.40	2.20	20.60	4.53	2.30	2.20	2.05
	45	14.95	2.23	20.60	4.60	2.33	2.20	2.00
	60	14.70	2.21	20.60	4.70	2.30	2.22	2.21
	75	15.12	2.30	20.70	4.82	2.30	2.28	2.15
	90	15.27	2.32	22.80	4.92	2.50	2.40	2.03
LSD CS		1.14	0.18	2.56	0.98	0.12	0.20	0.16
LSD HA		0.52	0.20	1.20	1.10	0.16	0.19	0.15
Statistical significance:								
CS		*	*	*	NS	*	NS	NS
HA		*	*	*	NS	*	NS	NS
CS x HA		NS	NS	NS	NS	NS	NS	NS

Table 5. Micro-elemental contents of blue panic at two different growth stages, and at various levels of HA applications.

Treatments		Micro-minerals (mg kg^{-1} DM)					
Growth Stage (GS)	HA Level (Kg ha^{-1})	B	Mn	Fe	Co	Cu	Zn
Before flowering (BF) stage							
	0	4.51	62.55	80.44	0.02	6.72	22.96
	15	4.60	62.60	85.05	0.10	8.90	23.98
	30	4.60	62.60	90.84	0.10	8.80	25.90
	45	4.60	62.63	93.44	0.12	8.82	25.93
	60	4.68	62.60	93.13	0.12	8.86	25.91
	75	4.70	62.60	93.51	0.22	8.92	26.00
	90	4.73	62.80	93.52	0.23	8.92	26.02
After flowering (AF) stage							
	0	4.35	79.81	70.12	0.10	5.66	16.00
	15	4.40	80.02	74.17	0.10	6.70	18.12
	30	4.40	79.90	74.70	0.10	6.70	19.30
	45	4.43	79.90	75.25	0.12	6.70	19.30
	60	4.40	79.98	75.00	0.18	6.72	19.50
	75	4.40	80.00	75.42	0.20	6.78	19.34
	90	4.60	80.03	75.57	0.18	6.90	19.40
LSD GS		0.20	8.32	9.10	-	1.16	4.10
LSD HA		0.21	-	5.00	-	1.04	3.11
Statistical significance:							
CS		*	*	*	NS	*	*
HA		*	NS	*	NS	*	*
CS x HA		NS	NS	NS	NS	NS	NS

DISCUSSION

Results of the growth parameters, including plant height and DM, indicated that biomass was higher for cutting the plants at AF stage, compared with BF. However, subsequent nutrient analyses indicate that the feed value actually decreased at the later stage cutting, compared to first stage. This could be explained by decreasing leaf/stem ratios, as well as increases in cell wall materials, ADF, and NDF (Gidenne, 2015). Humic acid enhances crop growth parameters due to its positive effect on soil physical and chemical properties, and nutrient uptake, and it additionally decreases plant oxidative stress (Goto and Gordon, 1991; Daur, 2013, 2014). Based on the chemical analyses of the feed values, the blue panic had suitable crude protein content at BF stage, whereas at the AF stage, this value dropped below the optimal level for rumen functioning, which is 7.5% (van Soest, 1982). This change was attributed to increase in cellulose content, where protein content declines rapidly. This result suggests cutting of the crop at BF stage. In addition, compromising quantity with quality by utilizing the AF stage, then it will require supplementary proteins, for example from oilseed cakes, or non-protein nitrogen (NPN) sources such as urea, or biuret. It is also possible to achieve the required protein content by mixing the grass with high protein forage crops, such as alfalfa, berseem, or sesbania species. The observed lower ADF and NDF contents, combined with high DDM or DM values in the tender stages of a crop, are comparable to observations from previous studies (Theodoridou et al. 2011; Peiretti et al. 2013). This can be explained by the decline in plant tenderness due to development of xylem tissues for water transport, and the accumulation of cellulose and other complex carbohydrates in later stage of the plants. An optimum range of 17-21% ADF and 25-33% NDF for cows during their milk production peak has been suggested in the past (Kawas et al. 1991, Zebeli et al. 2008). However, our data for blue panic ADF and NDF contents were similar to many warm season grasses, including *Bothriochloa ischaemum*, *Cynodon dactylon*, *Eragrostis curvula* (Restelatto et al. 2014; Soto-Navarro et al. 2014). Recent studies indicate that exact quantifications of dietary ADF and NDF are difficult, because it involves feed intake behavior, ruminal mat formation, rumination and salivation, ruminal motility, and animal type etc (Zebeli et al. 2012, Soto-Navarro et al. 2014). Generally, forages with lower ADF and NDF contents are less filling, since they are highly digestible, and therefore allow a larger dry matter intake, which makes them desirable fodder for lactating animals. Nevertheless, the desirability of feed depends on its availability and purpose. For animals in late-lactation, dry cows, or heifers, blue panic from both growth stages can be very suitable, as the comparatively high ADF and NDF will sustain these animals. Furthermore, our results regarding the effect of HA on forage quality are supported by Nazli et al. (2014), who reported that leonardite (a raw source of HA) has positive effects on feed CP and ADF levels when mixing it with inorganic fertilizers.

The high mineral contents in early growth stages are common in almost all crops, because mineral absorption and dry matter production do not occur at the same rate. In

young blue panic grass, element absorption was relatively rapid, whereas dry matter production rather slow. Both results are in general agreement with earlier findings (Lee and Smith, 1972; Kilcher and Heinrichs, 1974; Rominger et al. 1975; Daur et al. 2011; Barker and Pilbeam, 2015). The increase in macro- and microelemental composition with increasing HA levels is attributed to the improvement of the soil's physical and chemical properties. Moreover, the unique structural characteristics of humic acids with large number of oxygen containing functional groups (CO_2H_2, OH, phenols, and C=O), play a key role to enhance nutrient availability by the chelation of metallic nutrient elements (Nardi, et al., 2009). Better root architecture and increased root area by stimulating root elongation and lateral root development have been reported as important phenomena responsible for improved nutrient uptake by humic acids (Canellas et al., 2002, 2011; Jindo et al., 2012).

All these ultimately lead to enhanced plant nutrient uptake, as reported by earlier studies (Yona and Aviad, 1990; Eyheraguibel et al. 2008; Daur, 2013).

The lack of significant effects of HA level on Ca, S, Na, and Co is most likely due to the already high levels of these elements in the soil. We discussed above how the blue panic N content relates to feed value through its CP values. In addition, the foliar P content was higher than 2 g kg^{-1}, and K content was higher than 8 g kg^{-1} for all treatments, which are both recommended levels for animal feed (Underwood, 1981; Main et al. 2013). Similarly, the blue panic Ca, Mg, S, and Na concentrations (6, 2, 1, and 1 g kg^{-1}, respectively) are considered adequate for animal feed as well (Sykes and Field, 1972; NRC, 1978, 1984, 1985: ARC, 1980, McDowell, 1985; Little, 1985; Minson, 2012, Knowles and Grace, 2014). The optimal dose of boron (B) for animals is not generally available from literature, although it was recently established as an essential element for animals (Kabu et al. 2015; Kabu and Uyarlar, 2015). In addition, the blue panic grass was found to be satisfactory for Mn and Fe, since 40 mg kg^{-1} for Mn, and 50 mg kg^{-1} for Fe, are considered adequate for farm animals (McDowell, 1985). Cobalt (Co) was found to be adequate in blue panic grass as 0.1-02 mg kg^{-1} of dry matter is required (NRC. 1985). However, it is rare for grasses to have enough Co to meet the demands of farm animals, because most foliage from pastures have 0.10 ppm or less Co (Hodgson et al. 1962). Finally, pastures with 8-14 mg kg^{-1} Cu, and 12-35 mg kg^{-1} Zn, are considered adequate for animals (McDowell *et al.* 1978; ARC, 1980).

CONCLUSIONS

This article underscores the potential for growing blue panic grass in saline conditions. Until today, this crop has not received much consideration because of the lack of scientific information about its feed value. In this article, we explore the feed value of blue panic grass more comprehensively, in order to fill this gap in the current literature.

The study suggests the application of 75-90 kg ha^{-1} HA to the soil, before sowing—to enhance both the yield and quality of the crop, whereas cutting of the crop at BF (before flowering) for quality feed, and AF (after flowering) stage for animals in late-lactation, dry cows, or heifers/ or with feed supplement for milking animals may recommended.

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