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INFLUENCE OF RICE STRAW MULCH ON SALINE SOIL : FORAGE PRODUCTION, FEED QUALITY AND FEED INTAKE BY SHEEP

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ABSTRACT

The utilization of saline soils requires appropriate management including planting of tolerant plants such as *Panicum maximum* and *Sesbania grandiflora*. The research was conducted to evaluate the effect of rice straw mulch in saline soil on forage production, feed quality and feed intake by sheep. This study was conducted during the dry season (April – September 2013) in saline soil in Kaliori sub-district area, Rembang Regency, Central Java Province, Indonesia. The experimental treatments were *P. maximum* monoculture without mulch (M1); *P. maximum* monoculture + 3 ton/ha mulch (M2); *P. maximum* monoculture + 6 ton/ha mulch (M3); *S. grandiflora* monoculture without mulch (M4); *S. grandiflora* monoculture + 3 ton/ha mulch (M5); *S. grandiflora* monoculture + 6 ton/ha mulch (M6); mixed cropping of *P. maximum* and *S. grandiflora* without mulch (M7); mixed cropping of *P. maximum* and *S. grandiflora* +3 ton/ha mulch (M8); mixed cropping of *P. maximum* and *S. grandiflora* +6 ton/ha mulch (M9). Rice straw mulch application in saline soil increased dry matter production and crude protein content of *P. maximum* and *S. grandiflora*. Application of 3 - 6 ton/ha mulch in saline soil sufficiently increased forage production and feed quality of *P. maximum* and *S. grandiflora*. Dry matter (DM) intake of *P. maximum* and *S. grandiflora* in this study was at the range of DM requirement of fattened sheep.

Key words : Dry matter intake, mixed cropping, *Panicum maximum, Sesbania grandiflora*

INTRODUCTION

Saline soil is characterized as the presence of excess salt on the soil surface and in the root zone (Abrol et al.1988). The effect of saline stress includes both ionic (chemical) and osmotic stresses (Xiong et al. 2002). Ionic stress occurs when excessive amount of salt enters the plant reaching toxic levels in the older transpiring leaves causing premature senescence. The reduced ability to take up water is an osmotic stress to plants in saline conditions (Munns 2002). The effect of ionic and osmotic stress will reduce plant growth.

Plants have varying tolerance to soil salinity conditions. Kusmiyati and co-workers (2012) tested five forage grasses (*Panicum maximum, Setaria sphacelata, Euchlaena mexicana, Brachiaria brizantha* and *Cynodon plectostachyus*) in saline soil with electrical conductivity (EC) of 11 dS/m. Among the five forage grasses tested, *Panicum maximum* (guinea grass) was the most tolerant plant based on mineral concentration. Qadir et al. (2008) reported that *Sesbania* has shown promise for biomass production on moderately saline sodic soil among the forage species. Salt tolerant plants could be grown in different cropping systems as pure stand/monoculture or mixed cropping.

Panicum maximum is a perennial bunch grass that is reasonably palatable for cattle (Fig. 1). This grass is well suited for cut and carry, a practice in which grass is cut and brought to ruminants in stalls. It has been used succesfully for making silage and hay. The leaves of this grass contain good levels of crude protein (Aganga and Tshwenyane 2004). *Panicum maximum* is a shade tolerant grass that makes it suited to coexisting with trees in agroforestry (Paez et al. 1997). *Sesbania grandiflora* is a small legume tree in the genus *Sesbania* (Fig. 2). The leaves of this legume is valued as a fodder for ruminant particularly during dry season throughout Indonesia (Van Eys et al. 1983b)

Fig. 1. *Panicum maximum*

Fig. 2. *Sesbania grandiflora*

Utilization of saline soils requires appropriate management. Water management that reduce evaporation from soil surface in saline soil will help to control root zone salinity. Mulch is one way to reduce evaporation. Salinity was found to be higher in the treatment without mulch than with different mulch materials (Rahaman et al. 2004). The beneficial effect of mulch on crop growth include reducing evaporation (Taban and Naeini 2006), conserving soil moisture content (Athy et al. 2006; Duppong et al. 2004), reducing soil temperature (Duppong et al. 2004), and increasing plant nitrogen and potassium content (Wang et al. 2008).

Little information is available on the effect of mulching in saline soil on forage production, feed quality and feed intake by sheep. The present study therefore sought to evaluate the effects of rice straw mulch in saline soil on *Panicum maximum* and *Sesbania grandiflora* forage production, feed quality and feed intake by sheep.

MATERIALS AND METHODS

Study area

This study was conducted during the dry season (April–September 2013) in saline soil in the Kaliori sub-district area, Rembang Regency, Central Java Province, Indonesia. Rembang regency is located on the northeast coast of Central Java Province where annual rainfall is 1140 mm $year^{-1}$. The soil type is alluvial with silt loam texture with a soil pH of7.89 (alkaline) and electrical conductivity (EC) of 8.7 dS/m. Organic matter content, total nitrogen, available phosphorus and potassium levels were 0.26%, 0.01%, 44.47 mg/kg and 1.21 Cmol/kg, respectively. Exchangeable potassium and sodium content were 1.21 Cmol/kg and 13.31 Cmol/kg, respectively, while cation exchange capacity was 22.99 Cmol/kg.

Stand establishment

The experiment was laid out in a randomized complete block design (RCBD) with three blocks. The experimental treatments were *P. maximum* monoculture without mulch (M1); *P. maximum* monoculture + 3 ton/ha mulch (M2); *P. maximum* monoculture + 6 ton/ha mulch (M3); *S. grandiflora* monoculture without mulch (M4); *S. grandiflora* monoculture + 3 ton/ha mulch (M5); *S. grandiflora* monoculture + 6 ton/ha mulch (M6); mixed cropping of *P. maximum* and *S. grandiflora* without mulch (M7); mixed cropping of *P. maximum* and *S. grandiflora* + 3 ton/ha mulch (M8); mixed cropping of *P. maximum* and *S. grandiflora* +6 ton/ha mulch (M9).

Soil tillage was done before planting. Each experimental plot was 4 m long and 4.5 m wide. *P. maximum* was planted at 100 cm x 75 cm in monoculture and in mixed cropping. *S. grandiflora* was planted at 100 cm x 75 cm in monoculture, while in mixed cropping, *S. grandiflora* was planted between *P. maximum* rows. Rice straw as mulch was applied on the soil surface of each plot according to the treatment. The organic fertilizer (cow dung) was added to the soil at 115 tons/ha. The recommended levels of nitrogen (60 kg N/ha/cutting), phosporus (150 kg P_2O_5/ha) and potassium (100 kg K_2O/ha) were applied using urea, SP-36 and potassium chloride (KCl), respectively.

P. maximum and *S. grandiflora* were planted at the same time. Two vegetative planting material (tillers) of *P. maximum* were planted per hole. Three seeds of *S. grandiflora* were buried at approximately 0.5 depth. Two weeks after planting, only one vigorous plant of *S. grandiflora* was allowed to grow. *P. maximum* was cut to a suitable height of 15 cm at four weeks after planting. During the first cut, the growth and production of grass were not recorded. The second cut of grass was done six weeks after the first cut and the third cut was done six weeks after the second cut. *S. grandiflora* was cut at 16 weeks after planting or at the same time with the third cut of grass.

Fresh forage yield was determined from plants within an area of 3 m^2 from the center of each plot, cut at 10 and 30 cm above soil, for *P. maximum* and *S. grandiflora*, respectively. One hundred grams of fresh forage yield was dried at 105ºC until the weight of sample was constant to measure dry matter percentage.

Data collection

Parameters measured were dry matter (DM) production, crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF) and feed intake by sheep. Dry matter production was calculated by multiplying dry matter percentage and fresh yield. Dry matter production of *P. maximum* was the sum of DM production at second cut and third cut. Crude protein, ADF and NDF of *P. maximum* were measured at third cut. Crude protein was determined using the procedure of the Association of Official Analytical Chemists (AOAC 1984). Acid detergent fibre and neutral detergent fibre were determined according to the method developed by Van Soest and co-workers (1991).

Land equivalent ratio (LER) was used to evaluate mixed cropping efficiencies with respect to monoculture/sole crops. It was expressed as LER = $M_a/S_a + M_b/S_b$, where M and S refer to mixed cropping and monoculture crop yield, respectively and the subscripts *a* and *b* indicate the component crops in the mixture.

P. maximum and *S. grandiflora* from saline soil were tested on four thin tailed sheep, weighing an average 21.77 $\pm$ 0.93 kg, 4.5 – 5 months old, and kept in individual pens. Water was provided *ad libitum.* Freshly chopped feed was given twice daily at 0700 hours and 1700 hour for seven days. Each sheep was fed with a fresh mixture of the two forages, i.e. *P. maximum* and *S. grandiflora* (3 kg for each). During the measurement period, refusals were collected once daily and weighed. Dry matter intake was calculated as the difference between the offered and the refused quantity on a dry matter basis.

Statistical analysis

Analyzed data of dry matter (DM) production, crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF) were done using analysis of variance, followed by Tukey's range analysis to compare the difference between treatments according to Steel and Torrie (1991).

RESULTS AND DISCUSSION

Forage production

Rice straw mulch on saline soil affected significantly dry matter production of *P. maximum* and *S. grandiflora* (Table 1). Dry matter production was significantly lower without mulch. Dry matter production of *P. maximum* or *S. grandiflora* at 3 tons and 6 tons per ha mulch were not significantly different. Maximum dry matter production of *P. maximum* or *S. grandiflora* were observed in monoculture with 6 ton/ha mulch. Minimum dry matter production of *P. maximum* or *S. grandiflora* were observed in mixed cropping without mulch. The increased dry matter production is due to the higher soil moisture content in the mulch treatment. Soil moisture content in treatments without and with mulch were 2.6 % and 7.2 %, respectively.

Higher soil moisture content, nutrient content and cation exchange capacity of the soil in the mulch treatment can boost growth and crop production. Pervaiz (2009) determined that mulching increased soil water content. The use of mulches improves the availability of potasium (K) in the soil (Adeniyan et al. 2008) while accumulation of nitrate in the soil was higher in mulch treatments (Coppens et al. 2006). The use of mulch also increases soil organic matter and cation exchange capacity (Athy et al. 2006).

Table 1. Dry matter production of *P. maximum* and *S. grandiflora.*

Treatments	*P. maximum*	*S. grandiflora*
	..................(g/m^2)..................	
P. maximum monoculture without mulch	207.5± 56.4[bc]	-
P. maximum monoculture + 3 ton/ha mulch	386.3± 63.4[a]	-
P. maximum monoculture + 6 ton/ha mulch	429.9±71.6[a]	-
S. grandiflora monoculture without mulch	-	107.8±39.1 [cd]
S. grandiflora monoculture + 3 ton/ha mulch	-	241.5±32.8 [ab]
S. grandiflora monoculture + 6 ton/ha mulch	-	263.5±42.2 [a]
Mixed cropping without mulch	194.7±72.3[c]	49.5±16.4 [d]
Mixed cropping + 3 ton/ha mulch	342.1±76.2[ab]	160.2±11.0 [bc]
Mixed cropping + 6 ton/ha mulch	394.9±66.3[a]	197.1±38.7 [abc]

Values within columns having the same superscript are not significantly different (P<0.05) using Tukey's range test.

Land equivalent ratio (LER) was higher than one in all of the mixtures indicating a yield advantage over monocrop (Table 2). The highest LER (1.7) for dry matter production was obtained in mixed cropping of *P. maximum* and *S. grandiflora* at 6 ton/ha mulch. Land equivalent ratio without mulch and 3 ton/ha mulch were 1.4 and 1.6, respectively. Land equivalent ratio ranged from 1.4 to 1.7 thus, 40% to 70% more land should be used in monoculture in order to obtain the same yield in mixed cropping. The mixed cropping *P. maximum* and *S. grandiflora* out-yielded the monoculture (LER>1). Mixed cropping uses environmental resources better than monoculture and competition between mixed cropping components is not high. LER greater than one was due primarily to the increase in water and nutrient availability for plants. Soil moisture content at *P. maximum* monoculture and *S. grandiflora* monoculture were 2.4 % and 3.8 %, respectively, while soil moisture content in mixed cropped *P. maximum* and *S. grandiflora* was 8.2 %.

Table 2. Land equivalent ratio (LER) values of different mulch treatments

Treatments		DM production of mixed cropping	DM production of monoculture	LER
		.... (g/m^2)	....	
Without mulch	*P. maximum*	194.7±72.3	207.5±56.4	1.4±0.1
	S. grandiflora	49.5±16.4	107.8±39.1	
3 ton/ha mulch	*P. maximum*	342.1±76.2	386.3±63.4	1.6±0.5
	S. grandiflora	160.2±11.0	241.5±32.8	
6 ton/ha mulch	*P. maximum*	394.9±66.3	429.9±71.6	1.7±0.3
	S. grandiflora	197.1±38.7	263.5±42.2	

Forage Quality

Crude protein, ADF and NDF content of *P. maximum* that was grown on saline soil were 7.8 – 12.1%, 30.1 – 35.0%, and 60.2 – 64.1%, respectively (Table 3). Forage quality of *P. maximum* obtained in this research was much higher than those reported by Babayemi and Barnikole (2006). It was reported that crude protein and NDF content of *P. maximum* in Nigeria, which has a tropical climate, were 7.35% and 69%, respectively. *P. maximum* in this research was cut before it was blooming and was done six weeks after the second cut (sixteen weeks after planting). While Babayemi and Barnikole (2006) analysed *P. maximum* samples that were collected from 1 and 2 years established plots.

Table 3. Crude Protein (CP), Acid Detergent Fibre (ADF) and Neutral Detergent Fibre (NDF) (%) content of *P. maximum* and *S. grandiflora.*

Treatments	***P. maximum***			***S. grandiflora***		
	CP	**ADF**	**NDF**	**CP**	**ADF**	**NDF**
P. maximum monoculture without mulch	7.8 ± 0.4^{b}	35.0 ± 0.7^{a}	62.0 ± 1.0^{a}	-	-	-
P. maximum monoculture + 3 ton/ha mulch	10.3 ± 0.8^{ab}	30.3 ± 0.8^{b}	63.6 ± 1.4^{a}	-	-	-
P. maximum monoculture + 6 ton/ha mulch	12.1 ± 1.9^{a}	30.1 ± 1.6^{b}	64.1 ± 1.5^{a}	-	-	-
S.grandiflora monoculture without mulch	-	-	-	20.8 ± 0.7^{b}	20.0 ± 1.6^{a}	30.3 ± 1.7^{a}
S. grandiflora monoculture + 3 ton/ha mulch	-	-	-	24.6 ± 0.4^{a}	20.3 ± 0.9^{a}	30.2 ± 1.5^{a}
S. grandiflora monoculture + 6 ton/ha mulch	-	-	-	23.4 ± 1.3^{ab}	20.6 ± 0.9^{a}	29.7 ± 0.3^{a}
Mixed cropping without mulch	8.0 ± 0.5^{b}	34.7 ± 0.9^{a}	61.8 ± 2.5^{a}	21.4 ± 0.3^{ab}	20.4 ± 1.4^{a}	30.5 ± 0.7^{a}
Mixed cropping + 3 ton/ha mulch	9.8 ± 0.6^{ab}	32.1 ± 1.9^{ab}	60.2 ± 2.4^{a}	22.1 ± 0.9^{ab}	20.5 ± 1.0^{a}	30.5 ± 0.6^{a}
Mixed cropping + 6 ton/ha mulch	9.9 ± 0.8^{ab}	32.2 ± 1.9^{ab}	60.4 ± 0.7^{a}	22.8 ± 2.2^{ab}	20.2 ± 0.2^{a}	30.1 ± 1.5^{a}

Values within columns having the same superscript are not significantly different (P<0.05) using Tukey's range test.

Crude protein content values between 20.8 – 24.6% of *S. grandiflora* planted in saline soil, as found in this research, were lower than the value of 33.78% reported by Nag and Matai (2000) for fresh leaf of *S. grandiflora* from Calcutta. On the other hand, ADF and NDF content of *S. grandiflora* obtained by this research in saline soil were 20.0% - 20.6% and 29.7% - 30.5%, respectively. These values were higher than 19.1% ADF and 23.2% NDF of *S. grandiflora* in Kenya, as reported by Wandera and co-workers (1991). The treatments affected significantly crude protein of *P. maximum* and *S. grandiflora*. Crude protein content of *P. maximum* monoculture without mulch treatment was significantly lower than with mulch treatments. Crude protein content of *P. maximum* or *S. grandiflora* were not significantly different for 3 ton/ha mulch and 6 ton/ha mulch (Table 3).

The effect of saline stress includes both ionic (chemical) and osmotic stresses (Xiong *et al.*, 2002). Ionic stress occurs when excessive amount of salt enters the plant to toxic levels in the older transpiring leaves causing premature senescence. The reduced ability to take up water is osmotic stress of plants in saline conditions (Munns 2002). Moisture content in saline soil without mulch application was lower, so plants grow under water stress. Costa *et al.* (2008) reported the plants subjected to water stress suffered, with corresponding decrease in the amounts of total protein caused by the decrease in their synthesis, and a fall in nitrate reduction activity caused by the low nitrate flux.

The other important characteristics for forage quality are the content of ADF and NDF. In general, digestible energy decreases as ADF increases. ADF content of *P. maximum* was significantly higher at no mulch treatment both at monoculture and mixed cropping, while ADF content of *S. grandiflora* was not affected by treatments (Table 3). Water stress of plants without mulch will encourage the generative phase of plant. Cell wall development increased at the time of flowering so, ADF content of grass will be higher at no mulch treatment.

Treatments did not affect NDF content of *P. maximum* and *S. grandiflora.* This result is in accordance with Suyama *et al.* (2007) who reported NDF content of wheatgrass, Paspalum, wildrye, bermuda grass and alfalfa were not significantly different among non- saline, moderately saline and highly saline irrigation water. Generally, high crude protein and low NDF are indicators of high forage quality. NDF is an esimate of the structural cell wall components of plants excepts pectins and consists of the slowest digesting fraction such as cellulose, hemicellulose, lignin and cutin. NDF content of forage was negatively correlated with dry matter intake of ruminants.

Feed Intake

Dry matter (DM) daily intake was 645.1 g/day and 230.6 g/day for *P. maximum* and *S. grandiflora*, respectively. Hence, total dry matter intake was 875.7 g/day. The intake of dry matter as percent of body weight was 4% (Table 4). Dry matter intake of *P. maximum* and *S. grandiflora* of fattened sheep in this study was within the range of DM requirement for fattened sheep as suggested by Ranjhan (1981), which is about 3–5%.

Table 4. Daily feed intake of sheep fed with *P. maximum* and *S. grandiflora*

Parameters	*P. maximum*	*S. grandiflora*	Total
	.... (g/kg $BW^{0.75}$)		
Dry matter intake	64.01±1.2	22.90±0.6	86.91±1.3
Crude protein intake	6.18±0.1	5.16±0.1	11.34±0.2
Acid Detergent Fibre intake	20.75±0.4	4.65±0.1	25.40±0.4
Neutral Detergent Fibre intake	39.71±0.8	6.92±0.2	46.63±0.7

Dry matter intake of *P. maximum* and *S. grandiflora* were 64.01 g/kg BW (body weight)$^{0.75}$ and 22.90 g/kg BW$^{0.75}$, respectively. Hence, total dry matter intake was 86.91 g/kg BW$^{0.75}$. Total dry matter intake of fattened sheep in this study was higher than that reported by Van Eys *et al*. (1983a). Total dry matter intake of sheep fed only *P. maximum* was 39.4 g/kg BW$^{0.75}$ (Van Eys *et al*. 1983a). The addition of *S. grandiflora* in this study increased dry matter intake. Dry matter intake in sheep was earlier demonstrated to increase with increasing amount of legumes (Rangkuti *et al*. 1983).

Crude protein intake was 11.34 g/kg BW$^{0.75}$. Crude protein intake for basic living of growing sheep was demonstrated to be 4.74 g/kg BW$^{0.75}$ (Kearl 1982). In this study, there is excess crude protein intake of 6.60 g/kg BW$^{0.75}$ which can be used for production purposes in the form of daily live weight gain. Factors affecting protein intake were feeding level and the protein content in the feed. High crude protein intake was expected to increase the amount of protein in the body retention of livestock to meet basic living and production requirements (Ranjhan 1981).

Acid Detergent Fibre (ADF) and Neutral Detergent Fibre (NDF) intake by sheep in this study were 25.40 g/kg BW$^{0.75}$ and 46.63 g/kg BW$^{0.75}$, respectively. The NDF content affected the ability of ruminants to consume feed (Van Soest 1994). NDF content greater than 50% would reduce the level of dry matter intake. NDF content of *P. maximum* in this study was high (62.0%), while the NDF content of *S. grandiflora* was 30.2%. The low NDF content of *S. grandiflora* will compensate the high NDF of *P. maximum.*

CONCLUSION

Rice straw mulch increased dry matter production and crude protein of *P. maximum* and *S. grandiflora* in saline soil. The application of 3-6 ton/ha mulch sufficiently increased forage production and feed quality of *P. maximum* and *S. grandiflora* planted in saline soil. Dry matter intake of *P. maximum* and *S. grandiflora* in this study was at the range of dry matter requirement of fattened sheep.

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