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Effect of Different Mulch Treatments on Growth and Forage Yield of Millet (Pennicitum Americanum L.) Under Arid Land Conditions

Saeed. M. J. Turkustani, Hussain. E. Osman and Mohammed. H. Almarshadi
Arid Land Agriculture Department,
Faculty of Meteorology, Environment and Arid Land Agriculture,
King Abdulaziz University

Abstract-: **In this study soil was covered with wheat straw in four rates (0, 10, 20 and 30 t / ha) to investigate effect of soil covering on growth and forage yield of millet (Pennicitum americanum L.) during two season spring and autumn of 2009. The results showed significant differences between the three growth stages (vegetative, flowering and fruiting stages) (different cutting periods) in all millet plant parameters (plant height, branch number, leaf area, fresh and dry forage yield and its components) studied during spring and autumn seasons. As for wheat straw covering treatments the results showed significant differences in the total millet fresh weight and its components stem and leaves in addition to plant height during spring, but for autumn season the results indicated significant differences between treatments in stem fresh weight and plant height. There is also significant interaction between cuttings and treatments for the total fresh weight, fresh weight of leaves and plant height during spring, with no significant interaction between cuttings and treatments during autumn season. Covering the soil with wheat straw have positive effects on growth parameters of millet crop.**

Key words: Millet (Pennicitum americanum L.), wheat straw

I. INTRODUCTION

van Donk et al. 2008 conducted an experiment to study the effect of covering the soil with residue on soil water content and corn yield at North Platte, Nebraska. Mean corn yield was 12.4 Mg ha-1 in the residue-covered plots, significantly greater than the bare-soil plots. Sinkevičienė et al. 2009 studied effect of covering soil with chopped wheat straw; peat; sawdust and grass on soil properties and crop yield. They found mulching significantly decreased soil temperature, and significantly raised soil moisture content throughout the experimental period, and the highest soil moisture content was in plots mulched with peat or sawdust. They also noticed higher amount of available phosphorus in the mulched soil plots, and also available potassium in the soil covered with grass. Also they detected mulching decreased weed density, and the grass-mulched plots significantly gave the highest crop yields. Soil mulching controls weed growth as weed is an important factor determining crop yields, (Bilalis et al., 2002; Radics & Bognar, 2004; Jodaugienė et al., 2006). Evaporation of water from soil can be reduced by covering soil with plant residues, and also soil temperature will be stable (Ji & Unger, 2001; Kar & Kumar, 2007). Sønsteby et al. 2004 mulched soil plots with wood chips and found significant increase in amounts of phosphorus and potassium levels in the leaves of the crop. They suggested that these nutrients have been released from decomposing mulches. (Sharma & Sharma, 2003; Singh et al., 2007) stated that soil mulching improves plant growth and yield. Gruber et al. (2008), found no effect of mulching with wood chips on crop yield. Kar & Kumar (2007) obtained higher potato yield and better crop growth were observed in plots with straw mulch, but (Johnson et al., 2004 and Döring et al. 2005) found that potato yields were similar in mulched and unmulched plots with no effect on mulching on potato yield. Zhang et al. 2015 evaluated the effects of mulching with various straw mulches on soil water content, grain yield, and water use efficiency (WUE) of winter wheat (Triticum aestivum), using three straw mulch rates; 3, 6 and 9 t / ha. the average soil water content in the 0–200 cm soil layer increased significantly by 0.7–22.5% WUE by 30.6%, 32.7% and 24.2% the yield by 13.3–23.0% with 3, 6 and 9 t / ha respectively ($P < 0.05$) compared to unmulched soil. Unger (1978) and Wicks et al.(1994) suggested that different amounts of straw mulch can have various effects on the yield, and that the crop yield is only increased with mulch amounts within certain ranges. Hares et al. 1992) showed that the inhibitory effect of straw mulch on soil evaporation with winter wheat could reach 63.2%, while Zhao et al.1996 found that the inhibitory rate of straw mulch during wheat growth period was 21.5%. Many studies have found that inappropriate mulching amounts can have negative effects, resulting in yield reductions (Gao and Li, 2005). Wicks et al.(1994) suggested that different amounts of straw mulch can have various effects on the yield, and that the crop yield is only increased with mulch amounts within certain ranges. Cook et al.(2006) also reported that a wheat straw mulch at a rate of 2000–4000 kg ha−1 increased the maize yield, whereas a straw mulch of 6000–8000 kg ha−1 greatly decreased maize production.

II. MATERIALS AND METHODS

Preparation of plots:

The experiment was conducted at the Agricultural Research Station of King Abdulaziz University at Hada Alsham north east of Jeddah, Saudi Arabia. The site was ploughed with

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chiezel plough levelled and divided into 16 plots each 25 square meters (5 x 5 m). The design used was complete randomized design with 4 replicates. The first season plantation was carried out in 20/3/2009 (spring) and the second in 20/9/2009 (autumn). Plots were divided into rows 15 cm apart, and millet was planted at rate of 25 kg / ha.

Fertilization:

Before planting potassium sulphate (K2 SO4) and super phosphate (P2 O5) was added at rate of 140 kg / ha as one dose, while nitrogen was added at 4 doses the first one after 15 days from planting and the last after 60 days from planting. Wheat straw covering was added after 3 weeks from germination, at rate of 0, 25, 50 and 75 kg / plot equivalent to (0, 10, 20 and 30 t / ha).

Climate of the study area:

Saudi Arabia is one of the driest countries in the world, with extremely low rainfall average per year. Climatic condition data of the study area (maximum, minimum, and means) of air temperature, relative humidity during the two crop seasons 2009 (spring and autumn) were collected from the meteorological station of Faculty of Meteorology, Environment, and Arid Land Agriculture at Hada Al-Sham Agricultural Research Station (Table 1 and 2).

TABLE (1) CLIMATE DATA OF THE STUDY AREA FOR SPRING SEASONS 2009.

month	Temperature degree ºC			Relative humidity (%)		
	minimum	maximum	mean	minimum	maximum	mean
Mar	14.8	37.4	18.7	19	98	68
April	14.5	41.3	35.15	20	97	68.5
May	15.8	46.4	39	23	97	71.5
June	19.1	45.2	41.7	21	95	68.5

TABLE (2) CLIMATE DATA OF THE STUDY AREA FOR AUTUMN SEASONS 2009.

month	Temperature degree ºC			Relative humidity (%)		
	minimum	**maximum**	**mean**	**minimum**	**maximum**	**mean**
September	19.2	44.2	41.3	24	98	73
October	19	41.1	39.5	20	99	69.5
November	17.5	35.4	35.2	29	98	79
Disambir	13.3	32.3	29.5	26	97	59.5

Data collection:

Plants were cut through three growth stages (vegetative, flowering and fruiting stages), and plants were removed from an area of 1 square meter inside each plot, for determination of the different parameters.

Statistical Analysis:

Factorial analysis for analysis of variance with SAS to compare between the different treatments, and also between different growth stages. Also interactions between treatments were analyzed.

III. RESULTS

Plant height (cm):

Results of the analysis of variance (table 3) show significant differences between wheat straw covering treatments in plant height during the three cutting periods (at vegetative, flowering and fruit growth) and also between cutting periods during both seasons autumn and spring. The average plant height ranged between 129 cm in the 1st treatment and 160 cm in the second treatment during spring, and between 168 cm in the 3rd treatment and 210 cm in the 2nd treatment during autumn season (table 4) with domination of autumn season in plant height compared to spring season (table 4). As for cutting periods the lowest plant height was attained in the 1st cutting with 98 cm and 140 cm, and the highest plant height was during the 3rd cutting with 186 cm and 210 cm for spring and autumn seasons respectively, with domination of autumn season in plant height compared to spring season (table 4).

Number of stem branches:

The analysis of variance (table 4) show significant differences between cutting periods (at vegetative, flowering and fruit growth) in number of stem branches and no significant differences between wheat straw covering *treatments* during both seasons autumn and spring. The number of stem branches varied between 60 in the 3rd cutting and 122 in the 2nd cutting, and between 97 in the 4th treatment and 111 in the 2nd treatment during spring. And during autumn, the lowest branch number was in the 3rd cut 138 and the highest number was in the 2nd cutting 170 with domination of autumn season compared to spring season.

Leaf area:

Table (4) illustrates analysis of variances between cutting periods and also between wheat straw treatments as regards millet leaf area. The results showed significant differences between cuttings, and no significant differences between treatments during both seasons. The highest leaf area was attained in 2nd cutting with 557 cm2 and the lowest LA was in the 3rd cutting with 238 cm2 during spring, and between 242 cm2 in the 1st cutting and 945 cm2 in the 2nd cutting during autumn season. And the treatment with the highest LA was the 3rd treatment with 414 cm2 and with the lowest LA was the 4th with 377 cm2 during spring with no significant differences between them. For spring season the treatment with the highest LA was the 4th (30 t / ha) giving 669 cm2, and that with the lowest LA was the 2nd (10 t / ha) with536 cm2 with no significant differences between treatments (table 4).

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TABLE (3): ANALYSIS OF VARIANCE OF PLANT HEIGHT, NUMBER OF BRANCHES AND LEAF AREA UNDER WHEAT STRAW MULCH TREATMENTS AND GROWTH STAGES OF MILLET DURING SPRING AND AUTUMN SEASONS 2009.

Source of variation	Replicate	growth stages	mulch treatments	GS x treatment	Error
Plant height (cm)	1388	33440**	2322**	4489*	430
Number of branches	2081	19144**	759	780	583
Leaf area (cm2)	30112	408397**	8302	6030	5115

NS: Not significant at P≤0.05
* : significant at P≤0.05
** : significant at P≤0.01

TABLE (4): MEANS OF PLANT HEIGHT, NUMBER OF BRANCHES AND LEAF AREA UNDER WHEAT STRAW MULCH TREATMENTS AND GROWTH STAGES OF MILLET DURING SPRING AND AUTUMN SEASONS 2009.

Source of variation	season	growth stages				Wheat straw mulch treatments				
		1st	2nd	3rd	LCD	1st	2nd	3rd	4th	LCD
Plant height (cm)	spring	98 c	165 b	186 a	15	129 b	160 a	151 a	156 a	17
	autumn	140 c	181 b	210 a	9	178 ab	210 a	168 b	175 b	11
Number of branches	spring	118 a	122 a	60 b	17	93 a	111 a	99 a	97 a	14
	autum	156 ab	170 a	134 b	22	145 a	156 a	148 a	150 a	16
LA (cm2)	spring	376 b	557 a	238 c	51	360 a	410 a	414 a	377 a	59
	autum	242 c	945 a	632 b	116	582 a	536 a	641 a	669 a	134

* Means followed by the same letter are not significantly different according to LSD at P≤0.05

Fresh weight of millet plants:
Stem, leaves and total fresh weight:
Analysis of variance results:

Table (5) illustrates significant differences between cutting periods, and also between wheat straw treatments as regards stem fresh weight during both spring and autumn seasons. For leaves and total fresh weight there are significant differences between cuttings and also between treatments during spring season, but in autumn there are significant differences between cutting periods and no significant differences between treatments.

Means of fresh weight of stem, leaves and total fresh weight:
Stem fresh weight

The average stem fresh weight ranged between 0.200 kg / m2 in the 1st cutting and 4.262 kg / m2 in the second cutting during spring, and between 2.392 kg / m2 in the 2nd cutting and 4.481 kg / m2 in the 3rd cutting during autumn season with domination of autumn season in stem fresh weight compared to spring season (table 6). As for wheat straw treatments the lowest stem fresh weight during spring was attained in the 1st treatment with 2645 kg / m2 and the highest stem fresh weight was 3.725 kg / m2 during the 4th treatment, and during autumn seasons the lowest stem fresh weight was 3.077 kg / m2 during 2nd treatment and the highest was 3.720 kg / m2 in the 1st treatment with domination of autumn season in stem fresh weight compared to spring season (table 6).

Leaves fresh weight:

The mean values (table 6) of leaves fresh weight show that the lowest fresh weight is in the 1st cutting 1.481 kg / m2 and the highest is in the 2nd cutting 2.440 kg / m2 during spring, while during autumn season the lowest leaves fresh weight is 1.678 kg / m2 in the 3rd cutting and the highest is 5.650 kg / m2 during the 2nd cutting with domination of autumn season. For the treatments the the lowest leave fresh weight is 1.695 kg / m2 in the 3rd treatment (20 t / ha) and the highest value is 2.041 kg / m2 in the 1st treatment (0.00 t/ ha) with no significant differences between treatments 1,2 and 4 during spring, while during autumn the lowest leaves fresh weight is 2.883 kg / m2 in the 3rd treatment and the highest is 3.166 kg / m2 in the 2nd treatment with no significant differences between the treatments.

Total fresh weight:

The mean values (table 6) of total millet fresh weight show that the lowest fresh weight is in the 1st cutting 3706 kg / m2 and the highest is in the 3rd cutting 6871 kg / m2 during spring, while during autumn season the lowest total fresh weight is 4.975 kg / m2 in the 1st cutting and the highest is 8.318 kg / m2 during the 2nd cutting with domination of autumn season. For the treatments the lowest total fresh weight is 4.820 kg / m2 in the 1st treatment (20 t / ha) and the highest value is 6.045 kg / m2 in the 4th treatment (30 t/ ha) with no significant differences between treatments 1,2 and 3 during spring, while during autumn the lowest total fresh weight is 6183 kg / m2 in the 3rd treatment and the highest is 6.891 kg / m2 in the 1st treatment with no significant differences between the 4 treatments.

TABLE (5): ANALYSIS OF VARIANCE OF STEM FRESH WT., LEAVES FRESH WT. AND TOTAL FRESH WT. UNDER WHEAT STRAW MULCH TREATMENTS AND GROWTH STAGES OF MILLET DURING SPRING AND AUTUMN SEASONS 2009.

Source of variation	Replicate	growth stages	mulch treatments	GS x treatment	Error
Stem fresh wt. (kg/m2)	679635 NS	2048734**	243107**	612482 NS	835700
Leaves fresh wt. . (kg/m2)	70924 NS	370658**	321102*	769331**	109969
Total fresh wt. . (kg/m2)	1070138 NS	10095677**	3633472*	2645607*	774340

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TABLE (6): MEANS OF STEM FRESH WT., LEAVES FRESH WT. AND TOTAL FRESH WT. UNDER WHEAT STRAW MULCH TREATMENTS AND GROWTH STAGES OF MILLET DURING SPRING AND AUTUMN SEASONS 2009.

Source of variation	season	growth stages				Wheat straw mulch treatments				
		1st	2nd	3rd	LCD	1st	2nd	3rd	4th	LCD
Stem fresh wt. (kg/m2)	spring	2.00 c	4.262 a	3.178 b	0.663	2.645 b	3.187 b	3.029 b	3.725 a	0.765
	autum	3.021 b	2.392 a	4.481 a	0.438	3.720 a	3.077 b	3.079 b	3.316 a	0.506
Leaves fresh wt. . (kg/m2)	spring	1.481 c	2.440 a	1.892 b	0.240	2.041 a	1.989 a	1.695 b	2.026 a	0.277
	autum	1.753 b	5.650 a	1.678 b	0.41	2.995 a	3.166 a	2.883 a	3.062 a	0..542
Total fresh wt. . (kg/m2)	spring	3.706 c	3.871 a	5.334 b	0.716	4.820b	5.366 b	4.975 b	6.095 a	0.826
	autum	4.975 c	8.318 a	6.143 b	0.797	6.891 a	6.500 a	6.183 a	6.341 a	0.921

* Means followed by the same letter are not significantly different according to LSD at P≤0.05

Dry weight of millet plants:
Stem, leaves and total dry weight:
Analysis of variance results:
Table (7) illustrates significant differences between cutting periods, and no significant differences between wheat straw treatments as regards stem and total millet dry weight during both spring and autumn seasons. For leaves dry weight there is no significant differences between cuttings and also between treatments during both season.
Means of fresh weight of stem, leaves and total dry weight:
Stem dry weight
The average stem dry weight ranged between 0.578 kg / m2 in the 1st cutting and 1.196 kg / m2 in the 3rd cutting during spring, and between 0.268 kg / m2 in the 1st cutting and 1.612 kg / m2 in the 2nd cutting during autumn season with domination of autumn season in stem dry weight compared to spring season (table 8). As for wheat straw treatments the lowest stem dry weight during spring was attained in the 1st treatment with 0.792 kg / m2 and the highest stem dry weight was 0.998 kg / m2 during the 4th treatment, and during autumn seasons the lowest stem dry weight was 0.928 kg / m2 during 3rd treatment and the highest was 1.071 kg / m2 in the 1st treatment with no significant differences between treatments in both seasons, with domination of autumn season in stem dry weight compared to spring season (table 8).

Leaves dry weight:
The mean values (table 8) of leaves dry weight show that the lowest dry weight is in the 1st cutting 0.446 kg / m2 and the highest is in the 3rd cutting 0.550 kg / m2 during spring, while during autumn season the lowest leaves dry weight is 0.410 kg / m2 in the 3rd cutting and the highest is 0.559 kg / m2 during the 2nd cutting with significant differences between cuttings in both seasons, with domination of autumn season. For the treatments the lowest leave dry weight is 0.459 kg / m2 in the 1st treatment (0.00t / ha) and the highest value is 0.540 kg / m2 in the 2nd treatment (20 t/ ha) with no significant differences between treatments during spring, while during autumn the lowest leaves dry weight is 0.443 kg / m2 in the 4th treatment and the highest is 0.540 kg / m2 in the 1st treatment with no significant differences between treatments during autumn, with domination of autumn to spring.
Total fresh weight:
The mean values (table 8) of total millet dry weight show that the lowest dry weight is in the 1st cutting 1.024kg / m2 and the highest is in the 3rd cutting 1.746 kg / m2 during spring, while during autumn season the lowest total dry weight is 0.761 kg / m2 in the 1st cutting and the highest is 2.170 kg / m2 during the 2nd (10 t/ha) cutting with domination of autumn season. For the treatments the lowest total dry weight is 1.251 kg / m2 in the 1st treatment (0.00 t / ha) and the highest value is 1.521 kg / m2 in the 4th treatment (30 t/ ha) with no significant differences between treatments during spring, while during autumn the lowest total dry weight is 1.385 kg / m2 in the 3rd treatment (20 t/ha) and the highest is 1.611 kg / m2 in the 1st treatment with no significant differences between the 4 treatments.

TABLE (7): ANALYSIS OF VARIANCE OF STEM DRY WT., LEAVES DRY WT. AND TOTAL DRY WT. UNDER WHEAT STRAW MULCH TREATMENTS AND GROWTH STAGES OF MILLET DURING SPRING AND AUTUMN SEASONS 2009.

Source of variation	Replicate	growth stages	mulch treatments	GS x treatment	Error
Stem dry wt. (kg/m2)	60673 NS	1530135**	89266 NS	87649 NS	15839
Leaves dry wt. . (kg/m2)	16018 NS	43406 NS	18084 NS	29836 NS	17912
Total dry wt. . (kg/m2)	110529 NS	86313**	163923 NS	15855 NS	135812

NS: Not significant at P≤0.05
* : significant at P≤0.05
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TABLE (8): MEANS OF STEM DRY WT., LEAVES DRY WT. AND TOTAL DRY WT. UNDER WHEAT STRAW MULCH TREATMENTS AND GROWTH STAGES OF MILLET DURING SPRING AND AUTUMN SEASONS 2009.

Source of variation	season	growth stages				Wheat straw mulch treatments				
		1st	2nd	3rd	LCD	1st	2nd	3rd	4th	LCD
Stem dry wt. (kg/m2)	spring	0.578 c	0.890 b	1.196 a	0.224	0.792 a	0.903 a	0.860 a	0.998 a	0.259
	autumn	0.268 c	1.612 a	1.180 b	0.224	1.071 a	1.022 a	0.928 a	1.059 a	0.258
Leaves dry wt. . (kg/m2)	spring	0.446 b	489 ab	550 a	97	459 a	540 a	466 a	516 a	0.112
	autumn	493 ab	0.559 a	0.410b	0.112	0.540 a	0.509 a	0.475 a	0.443 a	0.129
Total dry wt. . (kg/m2)	spring	1.024 c	1.379 b	1.746 a	0.256	1.251 a	1.443 a	1.326 a	1.521 a	0.308
	autumn	0.761 c	2.170 a	1.590 b	0.279	1.611 a	1.531 a	1.385 a	1.502 a	0.322

* Means followed by the same letter are not significantly different according to LSD at P≤0.05

IV. DISCUSSION

The results illustrate that millet yield of fresh weight reached 3.706, 6.872 and 5.334 kg / m2 for cuttings during vegetative growth, flowering stage and fruit stage during spring, and in autumn it reached 4.975, 8.308 and 6.143 kg / m2 respectively during the three stages. The average millet dry weight reached 1.024, 1.379, 1.746 kg / m2 during spring and 0.761, 2.170, 1.590 kg / m2 in autumn during the three growth stages respectively. The results indicate that the highest fresh and dry millet weight occurred during flowering stage (2nd cutting period) and that autumn is more favorable to spring in millet growth, and this may be due to differences in temperature and its role in participation of accumulation of the dry matter inside the plants during the different plant growth stages. Leaves participation in dry weight reached 64.8%, 25.8% and 25.9% in the three growth stages during autumn compared to 35.2, 74.2 and 74 % for the stem, and this high percentage of leaves during vegetative stage in this season might be due to low temperature during the first weeks of plant life thus encouraging more leaf growth. In the previous studies carried out by Badaruddin, et al. (1999) in Mucsico yield improved by (11%) under soil mulching with plant straw during hot spring season compared to cold winter, and this agrees with the present results where there is increases in the biomass and its components during autumn compared to spring. The results also indicated that covering soil with wheat straw positively affected plant height, number of stem branches and fresh weight of leaves and total fresh weight during spring. The 2nd treatment (10 t/ ha) proved to be more effective than the others, thus giving the highest plant height, number of branches and total leaves fresh weight. On the other hand the 4th treatment (30 t / ha) was more effective compared to other treatments and gave the highest total plant fresh weight. For the plant dry weight the highest stem, leaves and total dry weight during spring occurred in the 3rd cutting period (fruit stage), and during autumn in the 2nd cutting (flowering stage). Zhang et al. 2015 used three straw mulch rates; 3, 6 and 9 t / ha on growth of winter wheat (Triticum aestivum), they found water content in the 0–200 cm soil layer increased significantly by 0.7–22.5% , WUE by 30.6%, and yield by 13.3–23.0% compared to unmulched soil. Covering the soil with wheat straw showed no positive effects on increasing total millet dry weight and its components stem and leaves during all plant growth stages. It can be seen that mulching the soil with wheat straw positively and significantly affected millet plant height, number of stem branches, leaf area and total dry weight and its components, and also positively affected total plant fresh weight and its components stem and leaves but with no significant differences between treatments (0, 10, 20, 30 t / ha). The results obtained in this study agree with other research results documented by others. van Donk et al. (2008) found significant increase in corn yield by 12.4 Mg ha-1 in the residue-covered plots, than the bare-soil plots. Sinkevičienė et al. (2009) found mulching with peat or sawdust significantly decreased soil temperature, and significantly raised soil moisture content throughout the experimental period. They also noticed higher amount of available phosphorus in the mulched soil plots, and also available potassium in the soil covered with grass. Ji & Unger, (2001; Kar & Kumar, (2007) detected reduction in evaporation by covering soil with plant residues, and also soil temperature will be stable. On the other hand some researchers found that mulching at some amounts can have negative effects, and reduces yield production (Gao and Li, 2005). Wicks et al.(1994) suggested that the crop yield is only increased with mulch amounts within certain ranges. Cook et al.(2006) found wheat straw mulch at a rate of 2000–4000 kg ha−1 increased the maize yield, whereas a straw mulch of 6000–8000 kg ha−1 greatly decreased maize production.

V. CONCLUSION

The result of this study indicated significant differences between the different cutting periods in all millet plant parameters studied during spring and autumn seasons. As for wheat straw covering treatments the results showed significant differences in the total millet fresh weight and its components stem and leaves in addition to plant height during spring, but for autumn season the results indicated significant differences between treatments in stem fresh weight and plant height. There is also significant interaction between cuttings and treatments for the total fresh weight, fresh weight of leaves and plant height during spring, with no significant interaction between cuttings and treatments during autumn season.

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