EFFECTS OF RICE BRAN - MULCH ON THE GROWTH OF SORGHUM AND MILLET IN MAIDUGURI, SEMI-ARID NORTH - EAST NIGERIA.

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ABSTRACT

In 2009, an experiment was carried out under rain-fed conditions at two sites to evaluate the influence of three rates of rice bran-mulch on the growth of sorghum and millet on a sandy loam soil in Maiduguri, Semi-arid North-east Nigeria. The study comprised six treatments replicated four times and laid out in a split-plot design. Following land preparation, rice bran was uniformly applied on the soil surface. Crop cultural practices were carried out. Plant height, leaf area index, root perimeter and maximum rooting depth were measured at seedling establishment, vegetative growth, flowering and maturity stages. Data collected were subjected to statistical analysis. Throughout the growth period of sorghum and millet, 15 t/ha mulch application rate produced the tallest plants and highest leaf area index ($P \leq 0.05$), compared with 0 and 10 t/ha mulch rates at Site 1. At vegetative growth stage, 15 t/ha mulch rate resulted in significantly ($P \leq 0.05$) higher (96.88 cm) root perimeter than 0 (83.06 cm) t/ha mulch rate at Site 1. At crop maturity, 10 t/ha mulch rate produced significantly ($P \leq 0.05$) higher (172.63 cm) root perimeter than 0 (149.00 cm) t/ha mulch treatment at Site 1.

Keywords: Rice bran mulch, sorghum, millet, plant height, leaf area index, root perimeter, maximum rooting depth and semi-arid region.

INTRODUCTION

Sustainable agricultural production in Semi-arid regions may be attained through cultural practices that ensure more efficient use of the limited rainfall and declining irrigation water that characterize the region (Tolk *et al*., 1999). Management practices that maintain crop residue on the soil surface have been shown to enhance crop growth (Odofin, 2005). The aforementioned better growth was generally attributed to increased soil water content resulting from reduced evaporation and increased infiltration. In semi-arid regions of Nigeria and Ghana, sorghum (*Sorghum bicolor* (L.) Moench) and millet (*Pennisetum glaucum* (L) Br.) are only grown once a year under rain-fed condition, and are important crops and major staple food (Chiroma *et al.,* 2003; Ojeniyi *et al.,* 2009).

Crop residue management practices affect plant growth and development through their influence on soil properties. Sow *et al.,* (1997) reported that greater rooting density of sorghum under wheat residue-mulch was attributed to higher soil moisture content. Odofin (2005) reported significantly better maize seedling emergence under mulch than in the no-mulch treatment, and that, mulching generally improved early crop growth measured as plant height compared with bare soil, although, this improvement lasted for only a short period of time as plant height differences between treatments diminished progressively over time. Increase in root and shoot growth according to Ojeniyi *et al.,* (2009) is attributed to reduction in bulk density resulting from mulch application compared to no-mulch treatment. Similarly, Chiroma *et al.,* (2005) reported that mulch application irrespective of tillage practice gave rise to significantly better root growth of millet crop compared to zero mulch treatments. These observations may be attributed to higher soil moisture, and reduction in evaporative losses. The objective of this study is to determine the effects of rates of rice bran-mulch on the growth of sorghum and millet in a semi-arid environment.

MATERIALS AND METHODS

Description of the Study Area

A field experiment was conducted at two sites. Site 1 is located near Gate 2, in the Faculty of Agriculture Teaching and Research Farm (11^0 49′ N, 13^0 13′ E and 324 m above mean sea level), while Site 2 is situated in the Faculty of Agriculture orchard, opposite Centre for Arid Zone Studies complex (11^0 49′ N, 13^0 12′ E and 327 m above mean sea level), University of Maiduguri, Borno State.

The climate of the study area is the seasonal wet-dry, semi-arid type. The annual rainfall ranges between 600 and 900 mm as observed during a ten-year period, 2000 to 2009 (Department of Meteorological Services, Maiduguri). In addition, potential evapotranspiration usually exceeds rainfall for about 8 to 9 months during a given year (Grema and Hess, 1994) except during the rainy periods. The soils of the study area are sandy loam in texture, developed from Aeolian sand deposit. Site 1 is characterized by gentle slope, while Site 2 is nearly level plain. The vegetation of the study area is dominated by vast grassland with few scattered trees and shrubs (Department of Forestry, University of Maiduguri).

The experiment was laid out in a split-plot design with four replications. The test crops (sorghum and millet) represented the main-plot, while the residue rates (0, 10 and 15 tons/ha) represented the sub-plot treatments. The rates of residues (wheat straw and wood shavings) applied in the study area range between 4 and 10 tons/ha (Chiroma *et al.,* 2005; Chiroma, 2004).

Before the commencement of the experiment, soil samples were collected from three replicates of each treatment, at 0-15 cm and 15-30 cm depths. The soil samples were air-dried, passed through a 2 mm sieve for physico-chemical analysis following the procedures described in detail by Page *et al.,* (1982). Also, a representative sample of the crop residue (rice bran) was analyzed in the laboratory for its N, P, Org. C, K, Ca, Mg and Na contents following the procedures described in IITA (1979).

Rice bran-mulch was uniformly applied on the surface of plots measuring 8 m x 4 m, just before planting. Five to six Apron star treated sorghum (var. ICSV III) seeds were sown at a spacing of 40 cm within rows and 75 cm between rows, while millet (var. LCIC MV-2 (LCIC 9702)) seeds were sown at a spacing of

50 cm within rows and 75 cm between rows (BOSADP, 1993). The seedlings were thinned to two plants per stand two weeks after planting. Recommended fertilizer rate of NPK (64:32:30) kg/ha for sorghum and millet was applied in two split doses (BOSADP, 1993). Weeds removal was carried out manually at 2, 6 and 9 weeks after planting. Harvesting of matured grains was done at twelve weeks after planting.

Crop growth indices (plant height, leaf area index, root perimeter and maximum rooting depth) were measured at 3, 6, 9 and 12 weeks after planting, representing seedling establishment, vegetative growth, flowering and maturity stages, respectively. Plant height was measured on eight randomly selected, tagged plants within the net plot (five middle rows, measuring 3 m x 2 m and 3 m x 1.5 m respectively for sorghum and millet), from the base of the plant (soil surface) to the apex of the flag leaf with the aid of a 3.5 m long calibrated wooden pole. Leaf Area Index (LAI) was determined using data obtained from five plants tagged within the net plot following the modified length and width product measurement method (Dugje and Odo, 2006). Root growth development was measured by the destructive sampling method (Obisesan, 1986). The length, L (from the soil mark to the root tip) and width, W (distance along the widest portion of the entire root system) of the roots were measured using a metre rule. Root perimeter (root room), P, an index of exploratory ability of the root system, was estimated as 2(L+W) (Obisesan, 1986). The rooting depth on a given day was estimated by employing an empirical relationship developed by Borg and Grimes (1986).

The data obtained were subjected to statistical analysis (ANOVA) at 5% level of significance using Statistix 8.0 (2005). Where significant differences exist between treatments, the differences were separated using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Physico-Chemical Properties of Soils of the Experimental Sites

The physico-chemical properties of soils (0 – 15 and 15 – 30 cm soil depths) of Sites 1 and 2, and the chemical composition of rice bran (mulching material) are presented in Table 1. The soils of the experimental sites are slightly acidic and sandy loam in texture. They are classified as Typic Ustipsamment (Rayar, 1986). The organic matter content is low, and decreased with depth as expected. The available phosphorus content of these soils is low, total nitrogen is moderate high and base status of these soils is low according to the ratings for soil fertility by FAO (1984; 2004) and Esu (1991). Generally, Site 2 soils possess higher clay content and higher nutrient status than those of Site 1. Soils with considerably high clay content are usually associated with higher nutrient and water-holding capacity compared with those high in sands. It is therefore, not surprising that soils at Site 2 performed better Site 1 soils with respect to growth indices studied.

Table 1: Physico-chemical properties of soils of the experimental sites before cultivation and chemical composition of rice bran-mulch at Maiduguri, 2009

Parameters	Site 1	Site 2	Site 1	Site 2	Rice Bran (% Min. Content)
Soil Profile Depth, cm	0-15	0-15	15-30	15-30	
pH (1:2.5) in Water	6.25	6.20	6.33	6.34	
pH (1:2.5) in $CaCl_2$	5.56	5.69	5.17	5.76	
Electrical Conductivity, µS cm^{-1}	66.0	104.90	36.15	53.80	
Sand, g kg^{-1}	630.50	630.50	643.00	643.00	
Silt, g kg^{-1}	258.80	258.80	240.00	241.00	
Clay, g kg^{-1}	110.70	110.70	117.00	116.00	
Textural Class	SL	SL	SL	SL	
Organic Carbon, g kg^{-1}	5.00	4.83	2.78	4.68	2.52
Organic Matter, g kg^{-1}	8.62	8.33	4.79	8.07	5.04
Total Nitrogen, g kg^{-1}	2.58	2.30	1.30	2.23	0.19
C : N Ratio	2.02	2.08	2.13	2.10	12.99
Available Phosphorus, mg kg^{-1}	4.56	17.59	3.15	10.59	0.14
Exchangeable Calcium, cmol kg^{-1}	2.15	5.45	2.65	4.35	1.80
Exch. Magnesium, cmol kg^{-1}	1.50	1.90	1.35	2.10	1.73
Exch. Potassium, cmol kg^{-1}	0.64	1.31	0.49	1.03	0.03
Exch. Sodium, cmol kg^{-1}	0.46	0.56	0.48	0.65	0.04
Exch. Acidity ($H^+ + Al^{3+}$), cmol kg^-	0.70	0.65	0.95	0.95	
Cation Exch. Capacity, cmol kg^{-1}	4.75	9.22	4.97	8.12	
Effective C. E. C., cmol kg^{-1}	5.45	9.87	5.92	9.07	
Base Saturation, %	87.20	93.40	83.96	89.85	

Crop Growth Parameters

The differences in crop growth indices (plant height, leaf area index, root perimeter and maximum rooting depth) observed between sorghum and millet at the various growth stages are attributed to inherent differences between the two crop types at the two sites.

Plant Height

The plant height of sorghum and millet is presented in Table 2. Results obtained from this study show that 15 tons/ha mulch treatment consistently produced the tallest sorghum and millet plants at seedling establishment, vegetative growth, flowering and maturity stages at Site 1, while at Site 2, both 10 and 15 t/ha mulch application rates resulted in taller plants than the 0 t/ha at vegetative growth, flowering and maturity stages. These observations could be attributed to availability of higher soil organic matter and total nitrogen content arising from the application of 15 t/ha mulch at Site 1. Another reason for the tallest plants resulting from the highest mulch application rate could be the lower seasonal crop evapotranspiration under 15 t/ha mulch treatment compared with 0 and 10 t/ha mulch rates, as found in this study at Site 2 (Eze, 2014). Taller plants may have resulted from a conducive microclimatic environment created by more adequate mulch cover provided on the soil surface under 10 and 15 t/ha mulch rates at Sites 1 and 2, and higher leaf canopy cover as observed at Site 1. A similar report by Odofin (2005) indicated that mulching significantly increased maize plant height, although, the improvement observed diminished over time.

Table 2: Effects of crop and mulch on plant height (cm) of sorghum and millet at Maiduguri, 2009

Treatment	At seedling establishment stage			At vegetative growth stage			At flowering stage			At maturity stage		
	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined
A: Crop												
Type	11.24b	22.86a	17.05a	53.60b	113.91a	83.75b	95.44b	155.03b	125.24b	110.93b	160.25b	135.59b
Sorghum	14.86a	20.85a	17.86a	97.72a	116.66a	107.19a	180.39a	240.06a	192.22a	186.12a	207.92a	197.02a
Millet	0.35	1.59	0.69	3.15	7.21	2.21	5.98	4.71	1.24	5.29	3.70	1.36
SE±												
B: Mulch												
rate	10.96b	19.98a	15.47a	62.37b	101.66b	82.01b	121.63c	169.74b	145.68a	136.24c	173.28b	154.76a
0 t/ha	12.87b	22.84a	17.85a	71.54b	119.55a	95.55ab	137.97b	182.61a	160.29a	150.00b	187.38a	168.69a
10 t/ha	15.32a	22.75a	19.04a	93.07a	124.64a	108.86a	154.15a	186.28a	170.21a	159.33a	191.60a	175.46a
15 t/ha	0.89	1.53	2.12	4.74	6.61	10.29	5.91	4.70	10.25	3.98	4.55	8.49
SE±												
Interaction												
A x B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means with the same letter (s) in the columns are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level of probability.
NS: Not significant

Table 3: Effects of crop and mulch on leaf area index of sorghum and millet at Maiduguri, 2009

Treatment	At seedling establishment stage			At vegetative growth stage			At flowering stage			At maturity stage		
	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined
A: Crop Type												
Sorghum	0.027b	0.126a	0.077a	1.081a	2.562a	1.821a	2.236a	2.859a	2.547a	2.415a	2.551a	2.483a
Millet	0.053a	0.086a	0.069a	1.016a	1.272b	1.144b	0.853b	1.090b	0.972b	0.666b	1.208b	0.937b
SE±	0.004	0.023	0.012	0.088	0.104	0.065	0.223	0.138	0.137	0.185	0.119	0.101
B: Mulch rate												
0 t/ha	0.029b	0.090a	0.059a	0.854a	1.715a	1.284a	1.290a	1.929a	1.610a	1.361a	1.957a	1.659a
10 t/ha	0.032b	0.117a	0.075a	0.951a	2.116a	1.534a	1.466a	2.031a	1.748a	1.627a	1.923a	1.775a
15 t/ha	0.059a	0.111a	0.085a	1.340a	1.920a	1.630a	1.877a	1.964a	1.920a	1.633a	1.759a	1.696a
SE±	0.007	0.011	0.017	0.197	0.185	0.262	0.237	0.102	0.168	0.213	0.177	0.143
Interaction												
A x B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means with the same letter (s) in the columns are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5 % level of probability.
NS: Not Significant.

Leaf Area Index (LAI)

The leaf area index of sorghum and millet is presented in Table 3. At seedling establishment stage, 15 tons/ha mulch rate produced higher sorghum and millet crop canopy cover than both 0 and 10 t/ha mulch rate at Site 1. The reason for this observation could probably be due to the better soil surface cover arising from the 15 t/ha residue rate, similar to the findings of Akanbi and Ojeniyi (2007) and Ojeniyi *et al.,* (2009). However, residue treatments had no significant ($P \leq 0.05$) effect in the subsequent stages of growth, suggesting that the significant differences in LAI at seedling establishment stage was not sustained throughout the growth period.

Root Perimeter

The root perimeter of sorghum and millet is presented in Table 4, while the significant interaction effect of crop type and mulch treatment on the root perimeter of sorghum and millet is presented in Table 5. In this study, results obtained at Site 1 in which root perimeter was observed to be higher in the 15 t/ha mulched plots than in the 0 t/ha mulched ones at vegetative growth stage may be due to the observed higher soil organic matter and total nitrogen content and better soil surface cover under 15 t/ha mulch application rate at Site 1. At maturity stage, 10 tons/ha mulch rate resulted in a higher root perimeter than 0 ton/ha mulch rate due to the same reasons mentioned above. At Site 2, the combination of sorghum and both 10 and 15 t/ha mulch application rates gave the highest root perimeter at flowering stage. This may be due to the greater horizontal and vertical root extension exhibited by sorghum crop and the two mulch application rates. Another reason could be the higher soil organic matter and total nitrogen content under sorghum, and under 10 and 15 t/ha mulch treatments at Site 2. The higher grain yield of sorghum, and also the higher grain and stover yield under 10 and 15 t/ha mulch treatments may have been the benefit that accrued from the greater horizontal and vertical root extension exhibited by sorghum and the two mulch application rates at Site 2.

Table 4: Effects of crop and mulch on root perimeter (cm) of sorghum and millet at Maiduguri, 2009

Treatment	At seedling establishment stage			At vegetative growth stage			At flowering stage			At maturity stage		
	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined
A: Crop Type												
Sorghum	43.32b	61.63a	52.47a	84.40a	125.21a	104.80a	108.62a	125.92a	117.27a	153.00a	135.42b	144.21b
Millet	56.43a	58.30a	57.37a	96.33a	100.75b	98.54a	106.25a	122.54a	114.40a	167.08a	154.50a	160.79a
SE±	1.64	2.41	1.57	6.26	2.87	4.44	11.93	3.19	7.40	5.12	5.90	5.16
B: Mulch rate												
0 t/ha	50.08a	57.93a	54.00a	83.06b	114.25a	98.66a	105.44a	121.06a	113.25a	149.00b	141.50a	145.25a
10 t/ha	48.88a	63.08a	55.98a	91.16ab	111.19a	101.17a	106.50a	127.81a	117.16a	172.63a	147.38a	160.00a
15 t/ha	50.68a	58.89a	54.78a	96.88a	113.50a	105.19a	110.38a	123.81a	117.09a	158.50ab	146.00a	152.25a
SE±	3.46	4.91	3.92	4.07	5.71	7.00	6.89	5.85	5.91	8.52	6.10	5.94
Interaction												
A x B	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS

Means with the same letter (s) in the columns are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5 % level of probability.
*: Significant at 5 % probability level.
NS: Not Significant.

Table 5: Interaction effects of crop x mulch on root perimeter (cm) of sorghum and millet at flowering stage at site 2 at Maiduguri, 2009.

	Crop type	
Mulch rate	**Sorghum**	**Millet**
0 t/ha	112.25b	129.88ab
10 t/ha	130.75a	124.88ab
15 t/ha	134.75a	112.88b
SE ±	7.48	

Maximum Rooting Depth

The maximum rooting depth of sorghum and millet is presented in Table 6, the significant interaction effect of crop type and mulch treatment on the maximum rooting depth of sorghum and millet is presented in Table 7. The difference in maximum rooting depth between the mulched and zero-mulch plots was not significant. The relatively low annual rainfall and low drainage below the root zone in the study area (Eze, 2014) probably may be responsible for the observation of no significant difference in maximum rooting depth among the three mulch treatments. Differences in maximum rooting depth may have been masked by the scanty moisture received from rainfall and low drainage below the crop rooting depth during the growing season. Also, profile moisture content observed in this study show that differences in moisture content among mulch treatments did not extend beyond 30 cm depth in most cases at the two sites. The combination of sorghum and the three mulch treatments performed better than millet and all mulch combinations, with respect to maximum rooting depth at maturity stage at Site 1. This could be attributed to the greater root zone depth of sorghum (1.0 m) at Site 1 as observed in a related study (Eze, 2014). Also, the sorghum root zone was observed to be wetter than that of millet at this site at maturity stage. Furthermore, the combination of sorghum and 0 t/ha mulch rate had deeper root penetration than the combination of sorghum and 15 t/ha mulch due to higher moisture content exhibited by 0 t/ha mulch treatment at maturity stage at Site 1. The lower root zone moisture content under 15 t/ha mulch treatment could be due to higher depletion of root zone moisture under 15 t/ha mulch treatment which resulted in a higher plant height, grain yield and stover yield at Site 1, as found in this study.

Table 6: Effects of crop and mulch on maximum rooting depth (cm) of sorghum and millet at Maiduguri, 2009.

Treatment	At seedling establishment stage			At vegetative growth stage			At flowering stage			At maturity stage		
	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined
A: Crop Type												
Sorghum	14.60b	18.04	16.50b	24.80a	31.46a	28.13a	36.42a	31.71a	34.06a	96.00a	98.75a	97.38a
Millet	19.52a	18.30a	18.91a	30.06	30.69a	30.38a	32.50b	32.17a	32.33a	70.67b	86.33b	78.50b
SE±	0.41	0.41	0.38	1.86	1.54	1.68	0.96	2.55	1.69	2.57	2.83	0.74
B: Mulch rate												
0 t/ha	17.18a	17.91a	17.54a	25.56a	31.81a	28.69a	34.75a	30.19a	32.47a	84.63a	91.25a	87.94a
10 t/ha	16.34a	18.77a	17.56a	27.18a	30.69a	28.93a	33.75a	32.56a	33.16a	84.13a	96.88a	90.50a
15 t/ha	17.65a	18.36a	18.01a	29.56a	30.72a	30.14a	34.88a	33.06a	33.97a	81.25a	89.50a	85.38a
SE±	1.12	1.70	1.08	1.96	1.96	1.66	1.62	2.09	1.43	2.52	2.90	3.37
Interaction												
A x B	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS

Means with the same letter (s) in the columns are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5 % level of probability.
*: Significant at 5 % probability level.
NS: Not Significant.

Table 7: Interaction effects of crop x mulch on maximum rooting depth (cm) of sorghum and millet at maturity stage at site 1 at Maiduguri, 2009.

	Crop type	
Mulch rate	**Sorghum**	**Millet**
0 t/ha	101.00a	68.25c
10 t/ha	96.50ab	71.75c
15 t/ha	90.50b	72.00c
SE ±	3.89	

Means with the same letter (s) in the columns are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5 % level of probability.

As shown in Table 8, the significant difference found between the observed and expected maximum rooting depth of sorghum at Site 1 under 0, 10 and 15 t/ha mulch application rates implies that maximum rooting depth of sorghum cannot be predicted at site 1 using the Borg and Grimes (1986) equation. In contrast, no significant difference was found between the observed and predicted maximum rooting depth of millet under 0, 10 and 15 t/ha mulch rates at Sites 1 and 2, and in the combined data. Similarly, no significant difference was found between observed and predicted maximum rooting depth of sorghum under 0, 10 and 15 t/ha mulch rates at site 2 and the combined data. The implication of no significant difference between observed and expected values is that, maximum rooting depth of both sorghum and millet can be adequately estimated using the Borg and Grimes (1986) equation at the two sites. This will reduce the time, labour and resources usually associated with the field measurement of maximum rooting depth of sorghum and millet on a given period during the growing season.

Table 8: Comparative Analysis (Paired T-test) of mean field measured (observed) and predicted (expected) maximum rooting depth (cm) of sorghum and millet at Maiduguri, 2009.

Treatment			Maximum rooting depth (cm)			
Silt	**Crop**	**Mulch (t/ha)**	**Observed**	**Expected**	**Sandard Error**	**T-ratio**
1	Sorghum	0	43.90	33.90	1.842	5.43*
		10	42.36	32.61	1.957	4.98*
		15	42.60	32.06	2.324	4.53*
	Millet	0	37.16	39.87	2.830	2.57^{NS}
		10	38.34	30.86	2.921	2.56^{NS}
		15	39.07	31.23	3.092	2.54^{NS}
2	Sorghum	0	46.95	38.31	3.755	2.30^{NS}
		5	47.60	39.01	3.774	2.28^{NS}
		10	44.93	37.05	3.427	2.30^{NS}
	Millet	0	41.14	33.69	2.589	2.88^{NS}
		5	43.59	35.83	2.725	2.85^{NS}
		10	40.90	33.01	2.973	2.65^{NS}
Combined	Sorghum	0	44.18	35.20	3.109	2.89^{NS}
		5	44.11	35.19	3.053	2.90^{NS}
		10	43.77	34.71	3.053	2.97^{NS}
	Millet	0	39.15	31.78	2.698	2.73^{NS}
		5	40.96	33.34	2.811	2.71^{NS}
		10	40.98	33.09	3.021	2.61^{NS}

*: Significant at 0.05 level of probability; NS: Not Significant.

CONCLUSION AND RECOMMENDATIONS

From the findings in the present study, it is concluded that 15 t/ha mulch rate improved crop growth in most cases at the two sites. Fifteen t/ha mulch application rate is, therefore, recommended for the production of taller sorghum and millet plants at Site 1. Also, both 10 and 15 t/ha mulch application rates are recommended for the production of greater root perimeter at Site 1, and taller plants at Site 2.

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