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Growth rate and yields of a sorghum-sudangrass hybrid variety grown on a light and a medium-heavy soil as affected by cutting management and seeding rate

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Abstract. Light vs. medium-heavy soil, number of cuts and seeding rate were studied for their effect on growth rate and yields of cv. Nutri Honey, a sorghum-sudangrass hybrid grown in a field trial at Pawłowice (51º09´ N; 17º06´ E) in the years 2007–2009. The experiment site is part of the Department of Crop Production, Wrocław University of Life Sciences, Poland. The experiment was set up on two soils, light and medium-heavy, in mid-May. No interaction among the factors under study was found for the number of plants after emergence, number of shoots prior to harvest, or for the dry matter yield. Number of plants after emergence was significantly higher on the light soil. Conversely, number of tillers at the end of growth was higher on the medium-heavy soil. Increasing the number of cuts promoted tillering and increased the number of shoots as counted at the end of growth. Weather pattern was found to have the greatest impact on yields. In the favourable year of 2009 the yield of DM was 14.8 t ha^{-1}. Number of cuts significantly affected the yields of DM, the highest yields being obtained with a single harvest (16,0 t DM ha^{-1}). The hybrid Nutri Honey gave significantly higher yields on the medium-heavy soil (12,8 t DM ha^{-1}) than on the light one (10,5 t DM ha^{-1}). Increasing seeding rate by 100% had no appreciable effect on DM yields.

key words: sorghum-sudangrass hybrid, soil heaviness category, cutting frequency, growth rate, dry matter yield

INTRODUCTION

Over the recent years in Poland, the recurring drought spells combined with high incidence of corn smut, European corn borer, and western corn rootworm have prompted a search for alternative crops as a supplement to, or a partial replacement of, maize (Pyś et al., 2008). The genus *Sorghum* comprises numerous diversified annual spring-sown species which resemble maize in habit but which develop only tassels in which seeds are set. Under Poland's conditions, some varieties do not produce seeds altogether or the grains fail to reach full ripeness (Sitarski, 2008). Sorghum, being a C_4 species, is an efficient utilizer of solar heat and radiation. It is resistant to drought, tolerant of short periods of waterlogging, tolerates both salinization and alkaline soils (Śliwiński and Brzóska, 2008). During drought, the leaves of maize wither whereas those of sorghum fold up only to resume vegetation after rainfall (Sitarski, 2008).

Hybrids originate from matings performed between some types of fodder sorghum and sudangrass and are unknown from natural habitats (Tew et al., 2008). Hybrids may contain more fermenting sugars and give higher biomass yields than cultivars of fodder sorghum. Compared to maize or sorghum, the hybrids have a smaller leaf area with waxy bloom owing to which they are more resistant to drought. An advantageous trait of the hybrids is an increased number of adventitious roots which, under water stress, allow the uptake of water from deeper soil depths, continuation of growth and increase of biomass. Another beneficial trait of the hybrids is that they grow faster than sorghum and thereby are more competitive and suppress the growth of weeds (Clark, 2007). The most important feature of the hybrid varieties is their ability to regrowth when cut, a trait inherited from sudangrass. As opposed to maize or sorghum, the hybrids can be harvested several times a year and thereby supplement the shortages of roughage during the growing season.

On light soils and during drought the yields of dry matter and energy from sorghum-sudangrass hybrid varieties are higher than those from maize (Cole et al., 1996). In temperate climate zone fresh yield from hybrids released to farmers is 30–53 t ha^{-1}. High yielders in the periods of water deficit, sorghum-sudangrass hybrids give good yields also when moisture supply is abundant (Habyarimana et al., 2004).

The objective of the study conducted in the years 2007–2009 was to assess the yields of the hybrid Nutri-Honey

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(sorghum-sudangrass hybrid) under the climatic conditions of Lower Silesia. It was assumed that the soil conditions and crop management would influence growth rate and dry matter yields.

MATERIAL AND METHODS

The study comprises results obtained from an experiment laid out as a split-plot design on fields operated by the Department of Crop Production, Wrocław University of Environmental and Life Sciences, located at Wrocław-Pawłowice. The growth rate and dry matter yield of sorghum-sudangrass hybrid cv. Nutri-Honey was investigated as influenced by three factors:

I – soil heaviness cathegory: light soil – loamy sand; medium heavy soil – light loam (Table 1),
II – utilization management (1-, 2- and 3-cut schemes),
III – seeding rate (20 and 40 grains m^{-2}).

The light soil experiment was set up on an haplic arenosol rated as class V in terms of crop production potential. The medium-heavy soil was classified as stagnic luvisol and rated as class III (Table 1).

The plot size was 13.5 m^2 (9 m in length and 1.5 m in width). Each treatment was replicated four times.

Prior to seeding fertilizers were applied at rates: 100 kg N ha^{-1} as urea, 70 kg P_2O_5 ha^{-1} as triple superphosphate and 100 kg K_2O ha^{-1} as potassium chloride. The seeds of sorghum-sudangrass hybrid cv. Nutri-Honey developed by the Desert Sun Marketing Company were drilled using a plot drill "Wintersteiger" in mid-May. After emergence the number of plants per 1 m^2 was counted. During growth, 10 plants were measured for height at two-week intervals starting from the 5–6 leaf stage to the end of tasselling. Prior to harvest, number of tillers per 1 m^2 and tillering coefficient were determined, and plant samples were taken to be analyzed for yield components and dry matter content. Once the plants were cut their dry matter yield was determined. Under the 3-cut management, the first and the second cut were done at the end of shooting-beginning of tasselling. In the 2-cut scheme, the harvest was done at tasselling – beginning of anthesis. When cut only once, the plants were harvested in the milk-waxy ripe stage.

The results were subjected to ANOVA using the Statistica 9 package. Intervals of confidence were examined using Duncan's test at α = 0.05 level of significance. Within a cutting management, the mean, standard error and standard deviation were determined for dry matter content and the results were presented as frame graphs.

Table 1. Content of sand, silt and clay fractions (%) and particle size subgroup of the soils used in the study of the agronomic performance of sorghum-sudangrass hybrid.

Soil	Fraction sums			Particle size subgroup
	2.0–0.05 mm	0.05–0,002 mm	<0.002 mm	
light	83	14	3	loamy sand
medium-heavy	62	27	11	light loam

RESULTS

In the period of 2007–2009 weather conditions varied from year to year. Higher than the analogous long-term averages, the temperatures prevailing in April, May, July, August and September as well as the total rainfall in the period from April to July and in October made the year 2009 the most favourable to the growth and yields of the hybrid (Table 2). Very abundant rainfall at the period of the highest demand of sorghum for water (from mid-July through August) was also of advantage to that crop. In the growing season of 2007 the average air temperature was the highest whereas, at the same time, slightly lower than average rainfall sums were recorded. In 2008 the distribution of temperature was beneficial but the rainfall sums for May, June and September were lower than the long-term averages for those months.

No effect of factor-by-factor interaction on the number of plants after emergence or on the number of tillers before harvest was found (Table 3). The highest population density was recorded on the light soil at the higher seeding rate – an average of 28 plants plants m^{-2} (70% of the planned stand). Prior-to-harvest number of tillers was the highest on the medium-heavy soil when the hybrid was harvested under the 3-cut regime and at the seeding rate of 40 grains m^{-2} – resulting in 81.2 tillers m^{-2}. On an average, the post-emergence number of plants on the light soil was significantly higher (by 75%) than that on the medium-heavy soil reaching 20,8 plants m^{-2}. On the end of growth, the number of tillers was higher, though insignificantly, on the medium-heavy soil (by 12%). The tillering coefficient was 2.8 and 5.5 on the light and on the medium-heavy soil, respectively. Number of tillers at harvest increased with the number of cuts and in the 3-cut regime was higher by 68% and 5% than in the 1-cut and 2-cut regimes, respectively. The tillering coefficient increased with the number of cuts from 2.7 (one cut) to 5.1 (3 cuts) (Table 3). The field emergence capacity was higher at the seeding rate of 20 grains per 1 m^2 (56.5%). Increased seeding rate resulted in a decrease of field emergence capacity to 49%. Seeding rate had a significant effect on the number of tillers at the end of the growing period.

In the initial period, Nutri-Honey showed superior growth rate when grown on the light soil. Starting from the third measurement, an insignificantly higher growth rate was recorded on the medium-heavy soil (Fig. 1). There were no cutting regime-dependent differences in plant height in the initial period of growth. The first cut in the 2- and 3-cut regimes had a significant impact on the further growth rate of the hybrid. Towards the end of the growing

Table 2. Monthly averages of air temperature and sums of rainfall in the growing period of sorghum-sudangrass hybrid.

Years	Months							Average/ Sum
	IV	V	VI	VII	VIII	IX	X	
Mean monthly temperature								
2007	10.9	16.2	19.2	19.2	18.9	12.9	8.3	15.1
2008	8.9	14.3	18.8	19.8	18.8	13.2	9.6	14.8
2009	12.0	14.2	15.8	19.5	19.3	15.4	7.9	14.9
1976–2005	8.3	14.1	16.9	18.7	17.9	13.3	9.2	14.1
Sum of rainfall								
2007	2.7	50.3	69.2	92.4	52.8	46.1	21.7	335.2
2008	87.1	37.3	36.5	65.6	74.8	27.9	41.1	370.3
2009	30.9	67.6	141.7	134.2	53.5	12.0	76.0	515.9
1976–2005	30.5	51.3	59.5	78.9	61.7	45.3	32.3	359.5

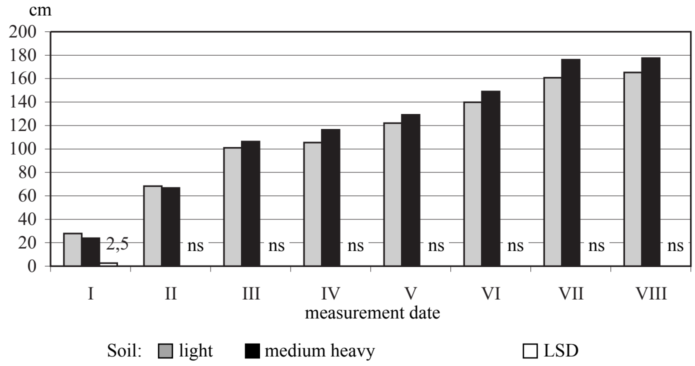
Table 3. Number of plants after emergence, number of tillers prior to harvest and tillering coefficient of sorghum-sudangrass hybrid.

Soil heaviness category	Cutting management	Number of grains per 1 m^2	Number of plants after emergence	Number of tillers prior to harvest	Tillering coefficient
light	1 cut	20	13.9	34.6	2.5
		40	28.1	43.3	1.5
	2 cuts	20	14.3	56.4	4.0
		40	26.3	74.9	2.8
	3 cuts	20	17.5	64.1	3.7
		40	25.0	76.9	3.1
medium-heavy	1 cut	20	9.8	40.5	4.1
		40	17.0	54.6	3.2
	2 cuts	20	9.2	66.6	7.3
		40	15.7	79.3	5.1
	3 cuts	20	7.0	71.2	10.2
		40	12.5	81.2	6.5
LSD(0.05)			ns	ns	-
Averaged across years					
light	-	-	20.8	58.4	2.8
medium heavy	-	-	11.9	65.6	5.5
LSD(0.05)			2.9	ns	-
-	1 cut	-	16.4	43.9	2.7
-	2 cuts	-	15.6	69.9	4.5
-	3 cuts	-	14.4	73.8	5.1
LSD(0.05)			ns	11.1	-
-	-	20	11.3	56.2	5.0
-	-	40	19.6	68.9	3.5
LSD(0.05)			2.5	10.0	-
Averaged across factors					
	2007		13.9	68.8	4.9
	2008		19.2	46.3	2.4
	2009		11.0	84.0	7.6
LSD(0.05)			3.5	11.1	-

ns – non significant

season, the tallest plants were recorded under the single harvest management, averaging 232.4 cm. Under the 2-cut management the hybrid reached the maximum of 166.7 cm in height whereas under 3 cuts the plants were 118.3 cm tall (Fig. 2). Seeding rate had no significant effect on plant height (Fig. 3).

The stalks accounted for the largest percentage of total yield components of the hybrid (from 60.5% under the



ns – non significant

Fig. 1. Effect of soil heaviness category on plant height in sorghum-sudangrass hybrid.

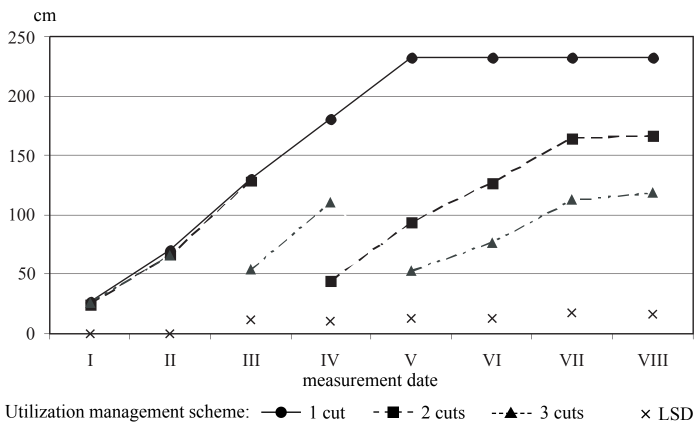


Fig. 2. Effect of cutting management on plant height in sorghum-sudangrass hybrid.

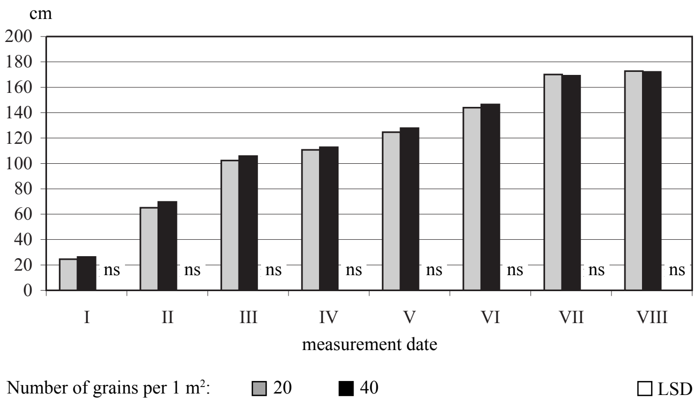


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Fig. 3. Effect of seeding rate on plant height in sorghum-sudangrass hybrid.

1-cut regime on the medium heavy soil to 72.4% from plants harvested twice on the medium-heavy soil) (Table 4). The tassels accounted for the smallest percentage (from 7.1% under three cuts on the light soil to 19.9% in the single harvest scheme, medium heavy soil). The percentage of tassels was the highest (14.8–19.9%) when the hybrid was managed under the single cut scheme which was related to the hybrid's reaching the waxy-ripe stage. The percentage of leaves in the total yield was the highest under the 3-cut management (from 21.0 to 31.5%). Higher number of grains per area unit on the light soil increased percentage of stalks on total yield. In medium-heavy soil. Higher stalks percentage accounted on lower sowing rate.

The different management schemes caused the plants of Nutri-Honey to be harvested at different development stages. Under a single harvest scheme, dry matter content was significantly higher, an average of 32%, than under 3 cuts – average of 18% (Fig. 4). The parameter was not found to be significantly affected by either the seeding rate or the soil heaviness category.

No factor-by-factor interaction was found to affect DM yield (Table 5). In the year 2009, the most favourable in terms of sorghum-sudangrass hybrid production, the significantly highest DM yield was obtained – 14.8 t ha^{-1}. When cropped to the medium heavy soil, Nutri-Honey gave a DM yield higher by 22% (12.8 t ha^{-1}) than when grown on the light soil (10.5 t per 1 ha). DM yield varied significantly depending on cutting management. The highest yield

Table 4. Yield components (% green matter) of sorghum-sudangrass hybrid.

Soil heaviness category	Cutting management	Number of grains per 1 m^2	Percentage of fresh yield		
			stalks	leaves	tassels
light	1 cut	20	62.3	21.0	16.8
		40	66.3	19.0	14.8
	2 cuts	20	69.3	21.6	10.9
		40	69.3	21.6	9.2
	3 cuts	20	61.3	31.5	7.3
		40	62.9	30.1	7.1
medium heavy	1 cut	20	62.5	20.2	17.4
		40	60.5	19.6	19.9
	2 cuts	20	72.4	18.4	9.3
		40	70.2	20.6	9.3
	3 cuts	20	68.4	21.0	10.6
		40	61.3	29.0	9.7

Table 5. Dry matter yield (t ha^{-1}) of sorghum-sudangrass hybrid.

Cutting management	Soil heaviness category			
	light		medium-heavy	
	Number of grains per 1 m^2			
	20	40	20	40
1 cut	14.3	16.9	15.1	17.4
2 cuts	9.2	10.9	11.8	13.7
3 cuts	5.6	5.9	9.2	9.7
LSD(0.05)	ns			

Average							
years		soil heaviness category		cutting management		number of grains per 1 m^2	
2007	9.3	light	10.5	1 cut	16.0	20	11.1
2008	12.5	medium heavy	12.8	2 cuts	11.6	40	12.6
2009	14.8	-	-	3 cuts	7.9	-	-
LSD (0.05)	2.0		1.7		1.5		ns

ns – non significant

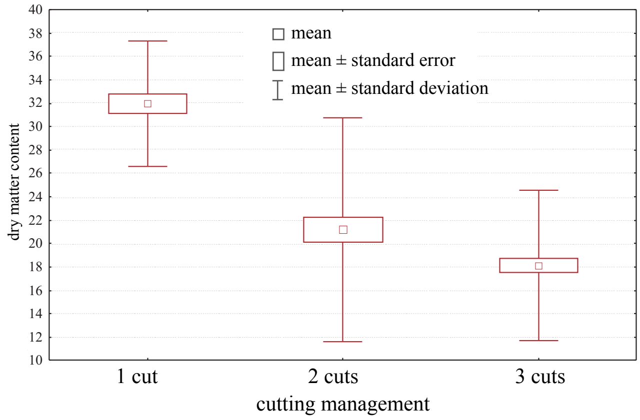

Fig. 4. Effect of cutting management on dry matter content of sorghum-sudangrass hybrid.

was obtained from a single cut scheme (16.0 t ha^{-1}). As the number of cuts increased there was a decrease in the DM yield: by 27.5% in the 2-cut scheme and by 50.6% in the 3-cut scheme. There was no effect of seeding rate on DM yield in the sorghum-sudangrass hybrid (Table 5).

DISCUSSION

The yields of the sorghum-sudangrass hybrid obtained over the years of the study were related to weather conditions prevailing in the growing season. Temperature and rainfall pattern in the critical stage of development affected plant yield significantly. During the growing season, sorghum requires ca. 250–300 mm of evenly distributed rainfall (Stichler et al., 1997). Moisture requirements decline rapidly once the grains have reached the waxy-ripe stage. In the study years the total rainfall in the growing season was higher than the requirement by that species but in the first year the rainfall was not evenly distributed which might have affected the yield.

The field emergence capacity (69.3% on the light soil and 39.7% on medium-heavy soil) was lower than that obtained in the study by Sowiński and Liszka-Podkowa (2008) for the tassel-less sugar sorghum G 1990, 75.5%, and for tasselled sugar sorghum (506) – 92%. Number of tillers at the end of growth was higher, 34.6 tillers m^{-2}, than in tassel-less sorghum, 17.8, or in tasselled sorghum 18.3 tassels m^{-2}. Hybrid varieties show a greater tendency to tiller than does sugar sorghum.

In this study, the highest dry matter yield was obtained under the single cut management (16.0 t DM ha^{-1}). In Uher's study (2005) the best results were recorded when the plants were cut after tasselling (27.4 t DM ha^{-1}). High yields were also obtained for a sorgum-sudangrass hybrid (24.2 t DM ha^{-1}) harvested at earing and at waxy-ripe stage (Lee, 2005).

In this study, insignificantly higher yields of dry matter were obtained when sorghum-sudangrass hybrid was seeded at 40 grains m^{-2}. Response of sorghum to seeding rate shows extensive variation and divergent results are reported in literature. Habyarimana et al. (2004) found dry matter yield to be dependent on seeding rate, genotype and availability of water. Under high moisture, at a plant density of 20 plants m^{-2} yields were higher than at a seeding rate of 10 seeds per 1 m^2. Under water stress, though, the results were comparable. According to the European Energy Crops Interwork (Habyarimana et al., 2004) the differences in yield at high (29 plants m^{-2}) vs. low (7 plants m^{-2}) plant densities were not valid statistically. Berenguer and Faci (2001) established that a density of 30 plants m^{-2} is more productive than that of 15 plants m^{-2}.

CONCLUSIONS

1. Temperature and moisture conditions of the Lower Silesia region ensured good growth and high yields of the sorghum-sudangrass hybrid Nutri-Honey originally cultivated in the US and Canada.
2. On a light soil, better temperature and moisture conditions ensured significantly higher number of plants after emergence. Superior soil fertility and more vigorous tillering shown by the hybrid contributed to its higher dry matter yields on a medium-heavy soil.
3. Increasing the number of cuts promoted tillering and decreased plant height of the hybrid.

4. Under a single cut regime, the sorghum-sudangrass hybrid showed a dry matter content that was optimum for ensiling. Increasing the number of cuts caused the DM content to fall below the optimum level. When grown under such management the hybrid must be ensiled with other crops that have a higher DM content or ensilage additives should be added. Alternatively, the crop can be used in a different manner e.g. fed directly to animals.

5. Defoliation and recovery of the assimilation area after cutting caused the yield of dry matter to decrease in proportion to the number of cuts. Compared to that under the 1-cut regime, the yields from cutting regimes involving 2 and three harvests were lower by 27.5 and 50.6%, respectively.

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