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Strategies of Growing several Sorghum Cultivars as a Post-Harvest Crop in North-Eastern Croatia Condition

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Summary

Recent climate changes lead toward possibility of using longer period of higher temperatures after winter crops harvest for establishing post-harvest crop, such is sorghum. It can produce significant biomass, useful both for feed and bioenergy, even in drier summers, with reduced soil tillage preparation. The trial was set up in Poljanci, Croatia, in years 2015 and 2016 as a split-plot design with foliar fertilizers and sorghum cultivars treatments, established by diskharrowsing soil after winter wheat harvest in mid-July, and harvested before autumn frosts at the end of November. Foliar fertilizers treatments were C) Control (no fertilization), B) Biological (Condi agro) and M) Mineral (EcoTop Folimax) foliar fertilizers. Cultivars used in trial were KSH3723, KSH3724, Lemnos, Leonie, Merlin, Sammos, Santos, Sole, Tarzan and Zerberus. Foliar fertilizer treatments B and M showed higher dried biomass yield for 7 and 11% in comparison with C, respectively. Difference between treatments were higher at fresh biomass yield. Treatments B and M showed 12 and 22% higher fresh biomass yield than C, respectively. Regarding the tested sorghum cultivars, the highest fresh biomass yield was recorded for Leonie (32933 kg ha⁻¹), followed by Lemnos (27467 kg ha⁻¹) and KSH3724 (26600 kg ha⁻¹), whereas the lowest yield was recorded for Zerberus (19600 kg ha⁻¹).

Key words

sorghum, post-harvest crop, foliar fertilizers

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Introduction

Usually, high yields in modern agriculture are possible due to genetic potential of crops and applied crop growing technics, were fertilization ads up to 50% of crop yield (Stewart et al., 2005). Nitrogen is one of the most important nutrient used in agricultural systems and contributes strongly to the sustainability, resilience, economical performance, and improvement of cropping systems (Delgado and Shaffer, 2008); however, nitrogen use efficiency is usually reported to be lower than 50% (Newbould, 1989) and the losses of added nitrogen fertilizers can be very significant (Wu et al., 2005). Today, the imperative is to continue the development, estimation, and adoption of new management practices that increase nitrogen recovery and reduce potential losses to the environment (Delgado and Shaffer, 2008). One of the potential solutions which may contribute to reducing environmental pollution by excess nitrogen from fertilizers is foliar fertilizers application, since the total amount of applied nutrients is significantly lower, with higher utilization ratio (Kettlewell and Juggins, 1992). Use of the combined NPK foliar fertilizer for different crops is more common (Kannan, 2006), but results are not always positive (Haq and Mallarino, 2000) so there is a need for further research to determine actual effectiveness. Another way to reduce the nitrogen leaching is the introduction of summer catch crops in crop rotation in the period between winter and summer cash crops. Summer crops can be used for food production, fodder, green manure and bio-energy (Kemp, 2011), thus ensuring extra profit, contribute to sustainability, resilience and also to diversification of both, production and market. Furthermore, grown as a post-harvest crop, they can utilize nitrogen, which remained after the main crop was harvested (Lochart and Wiseman, 1983), and thus reduce leaching and prolong the cycle of circulation of nitrogen in the soil. Summer catch crops are usually grown in unfavorable weather conditions (summer spell or summer precipitation deficiency) in which usual technology based on moldboard ploughing and mineral granular fertilizer incorporation in soil often does not result with positive effects. In recent years, many investigations showed the need for climate change mitigation in certain aspects of crop production (Bayhan et al., 2006, Kovačević et al., 2007, Birkas et al. 2008, Stipešević et al., 2011). Sorghum (*Sorghum bicolor*) is one of the potentially utilizable crops for that role, especially due its drought resilience (Cattivelli et al. 2008), with also long history of breeding for that trait (Rosenow et al. 1983). However, the biggest problem is to find the best suitable cultivar for given environment and role in crop rotation. Therefore, the aim of this study was to determine effects of different cultivars and foliar side-dressing cropping systems for sorghum sown as post-harvest crop.

Materials and methods

The field experiment was carried out on the Family Agricultural Enterprise (FAE) "Stipešević Ivica" near Poljanci, Croatia, during the summers of 2015 and 2016. The soil type was the eutric cambisol, with favorable crop production properties. The climate is moderate subhumid continental type. The preceding crops in both years was winter barley (*Hordeum sativum* L.). In both years, the agrotechniques for preceding crops included soil preparation by conventional tillage, based on autumn moldboard ploughing before fine seedbed preparation by disk harrowing and seedbed cultivator and usually recommended fertilization for both crops (120 kg N, 100 kg P and 120 kg K per ha). Soil tillage preparation for sorghum was single passage by heavy disk harrow up to 15-20 cm, followed by seedbed preparation cultivator, with coarse seedbed preparation and over 50% of soil surface covered by previous crop's residues. Pre-seeding fertilization was omitted for post-harvest sown sorghum. The seeding was performed with available cereal seeders at the row distance of 30 cm, depth of 2-3 cm and targeting seeding density of 30-35 grains m⁻². In year 2015 seeding had been performed in the second week of July, and in year 2016 in the first week of July. The experiments in both years were set up as the split-plot design in four repetitions, with ten levels of sorghum cultivars and three sub-levels of side-dressing, with basic experimental plot size for side-dressing of 2 m x 5 m. The sorghum (*Sorghum bicolor*) cultivars used in trial in both years were: KSH3723, KSH3724, Lemnos, Leonie, Merlin, Sammos, Santos, Sole, Tarzan and Zerberus. Used foliar fertilization sub-treatments were: C) no-side-dressing control; B) Biological foliar fertilizer (Condi agro), with several aerobic and anaerobic microorganisms, including bacteria, actinomycetes, yeasts and mildews, in rate of 7 l ha⁻¹ in two sprayings; and M) Mineral foliar fertilizer (EcoTop Folimax) which contains both macro (N, P, K, Ca) and micro (B, Cu, Fe, Mn, Mo and Zn) nutrients, in rate of 5 l ha⁻¹ in two sprayings. Side-dressings were performed 4 and 6 weeks after the seeding in each year. Harvests were performed manually in the last week of October 2015 and first week of November 2016. Harvested sorghum biomass was weighted and sub-sampled. Plant sub-samples were dried up at 60°C and than weight for moisture content estimation. The statistical analysis of the variance (ANOVA) of experiment was performed by SAS statistic package (V 9.1, SAS Institute, Cary, NC, USA, 1999). The Fisher protected LSD means comparisons were performed for P=0.05 significance levels for year, cultivar, side-dressing and their interactions.

The weather during both seasons is presented by Table 1. The summer 2015 was hot, with unequal and unusual precipitation pattern; July was very dry, August and September had normal

Table 1. Weather conditions in summer 2015 and 2016, weather station Slavonski Brod, Croatia

		July	August	September	October		
T (°C)	2015	24,9	23,5	17,6	11,4	Means	19,4
	2016	23,1	20,3	17,2	10,2		17,7
P (mm)	2015	15	79	71	144	Sums	309
	2016	141	28	67	64		300

precipitation level, whereas October was extremely wet. On the other hand, the summer 2016 was slightly less hot, with very wet July, dry August, normal September and October.

Results and discussion

The highest sorghum fresh biomass yield in 2015 was achieved by cultivar Leonie (Table 2) with average of 38 t ha⁻¹ of biomass, which was not significantly higher than following cultivar Sole, with 25.9 t ha⁻¹ of biomass. Statistically lower than Leonie, but at the same level of significance, were cultivars Merlin, Santos, KSH 3724, Tarzan and Lemnos, with yields ranging from 24.1 to 22.9 t ha⁻¹ of biomass. The lowest yield in 2015 had cultivar Sammos, with only 17.4 t ha⁻¹ of biomass. Dried biomass yield (Table 3) showed similar sequence of yields for cultivars, with cultivar Leonie being with the highest yield (8.8 t ha⁻¹ of dry biomass), followed by cultivar Sole (6.8 t ha⁻¹ of dry biomass) and finishing with cultivar Sammos being with the lowest yield (only 3.6 t ha⁻¹ of dry biomass). Cultivar Lemnos was with the highest fresh biomass yield in 2016 (Table 2) and with 32 t ha⁻¹ of biomass it was significantly better than following cultivar KSH 3724, which yielded 29.6 t ha⁻¹ of biomass. Following cultivars Sammos, KSH 3723 and Leonie had yield from 29.3 to 27.9 t ha⁻¹ of biomass. The lowest biomass yield in 2016 was recorded for cultivar Sole, with only 19.5 t ha⁻¹. Dry biomass yield (Table 3) had similar sequence of yields for named cultivars. Cultivar Lemnos recorded 8 t ha⁻¹ of dry biomass, significantly better than following cultivar KSH 3724 (7.2 t ha⁻¹ of dry biomass). Cultivars KSH 3723, Leonie, Santos and Sammos produced significantly lower dry biomass yields, ranging from 6.6 to 6.1 t ha⁻¹. The lowest dry biomass yield was recorded for cultivar Sole, with only 5.1 t ha⁻¹. In average of both years, cultivar Leonie was with the highest biomass yield of 32.9 t ha⁻¹ (7.6 t ha⁻¹ of dry biomass). Following cultivar Lemnos had significantly lower biomass yield of 27.5 t ha⁻¹ (6.9 t ha⁻¹ of dry biomass). Significantly lower biomass yielded cultivars KSH 3724 and Santos, with biomass yields of 26.6 and 23.4 t ha⁻¹ (6.4 and 6.2 t ha⁻¹ of dry biomass), respectively. Following cultivars had below 25 t ha⁻¹ of biomass (6 t ha⁻¹ of dry biomass), whereas the lowest yield was recorded for cultivar Zerberus, with only 19.6 t ha⁻¹ (5.3 t ha⁻¹ of dry biomass). Differences among cultivar's performances in different growing seasons (2015 being more dry and warmer at the beginning than 2016) can be partially be explained with differences in rooting depth, where same cultivar can have deeper rooting in drier environment, thus reacting better in rest of the season through adaptation of rooting and internal xylem structure, as described by Salih et al. (1999). Also, special emphasis in modern cultivar selection, such as KSH 3723 and KSH 3724, is given to "stay green" effect, where "stay green" materials tend to root deeper than senescent cultivars (Vadez et al., 2007), thus adopting better to harsher environments.

In both years, both B and M foliar fertilizers produced additional biomass of all sorghum cultivars in comparison with control treatment, but without statistical significance. However, trends shows 13% higher fresh biomass yields with B foliar treatment (ranging from 5 to 31% higher yields in comparison with control) and 22% higher fresh biomass yields with M foliar treatment (ranging from 13 to 35% higher yields in comparison with control). Positive effects of foliar fertilization has been presented by different authors (Wittwer and Teubner, 1959; Be and Scagel, 2007; Fernandez and Eichert, 2009), especially for plants in early development, due to better foliar absorption rates of younger leaves. Giskin and Efron

Table 2. Average fresh biomass yield (kg ha⁻¹) of sorghum cultivars and applied foliar treatments, Poljanci site, years 2015 and 2016

Cultivar	Control	Condi Agro	EcoTop Folimax	Cultivar mean	Rank
Year 2015					
KSH 3723	17200	20800	25600	21200 c	8
KSH 3724	22800	23600	24400	23600 b	4
Lemnos	22400	23000	23400	22933 b	7
Leonie	35400	38800	39800	38000 a	1
Merlin	23600	24800	24000	24133 b	3
Sammos	16800	18000	17400	17400 d	10
Santos	20800	22400	27600	23600 b	4
Sole	25600	26400	25800	25933 ab	2
Tarzan	20800	26000	22800	23200 b	6
Zerberus	16000	19600	19200	18267 d	9
Foliar mean	22140 a	24340 a	25000 a	23827 y	
Year 2016					
KSH 3723	25200	28400	31600	28400 bcd	4
KSH 3724	27200	29600	32000	29600 b	2
Lemnos	28000	30000	38000	32000 a	1
Leonie	24800	26000	32800	27867 cd	5
Merlin	20400	27200	27600	25067 e	7
Sammos	26400	30000	31600	29333 bc	3
Santos	24800	26800	30000	27200 d	6
Sole	14400	20400	23600	19467 g	10
Tarzan	17200	23600	25600	22133 f	8
Zerberus	18800	19200	24800	20933 g	9
Foliar mean	22720 a	26120 a	29760 a	26200 y	
Both years mean					
KSH 3723	21200	24600	28600	24800 de	5
KSH 3724	25000	26600	28200	26600 bc	3
Lemnos	25200	26500	30700	27467 b	2
Leonie	30100	32400	36300	32933 a	1
Merlin	22000	26000	25800	24600 de	6
Sammos	21600	24000	24500	23367 ef	7
Santos	22800	24600	28800	25400 cd	4
Sole	20000	23400	24700	22700 f	8
Tarzan	19000	24800	24200	22667 f	9
Zerberus	17400	19400	22000	19600 g	10
Foliar mean	22430 a	25230 a	27380 a	25013	

Means labeled with the same lowercase letter for same Cultivar or Foliar side-dressing average in each Year or Means group are not statistically different at P>0.05 significance level.

(1986) also found higher silage yield of maize with foliar fertilizers. Foliar fertilization with organic components and growth stimulators gave higher leaf yield and more aromatic compounds of *Mentha piperita* var. *citrate* (Hendawy et al., 2015) through better physiological processes in plant, which corroborate to results of applying B foliar treatment. However, Hu et al. (2008), found no higher maize growth, but, they contributed lack of foliar fertilization to maize growth to soil saline conditions.

Also, it is interesting to point out that differences between biomass yields as result of applied B and M foliar treatments were 9%, but, only five cultivars had additional yield higher than 10% with M treatment in comparison with B treatment, where 10% is arbitrary level of treatment's differentiation. This finding may indicate

Table 3. Average dry biomass yield (kg ha⁻¹) of sorghum cultivars and applied foliar treatments, Poljanci site, years 2015 and 2016

Cultivar	Control	Condi Agro	EcoTop Folimax	Cultivar mean	Rank
Year 2015					
KSH 3723	3970	4801	5909	5355 ef	8
KSH 3724	5959	5764	5568	5666 e	6
Lemnos	5899	5798	5646	5722 de	5
Leonie	8049	8822	9049	8822 a	1
Merlin	5555	5740	5463	5601 e	7
Sammos	3631	3756	3506	3631 g	10
Santos	5017	6182	4659	6182 cd	4
Sole	6784	6942	6732	6837 b	2
Tarzan	6118	5581	6976	6225 c	3
Zerberus	5233	5342	4361	4851 f	9
Foliar mean	5621 a	5873 a	5787 a	5889 y	
Year 2016					
KSH 3723	5817	6556	7295	6556 c	3
KSH 3724	7109	7229	7303	7214 b	2
Lemnos	7373	7562	9169	8035 a	1
Leonie	5639	5912	7458	6336 cd	4
Merlin	4802	6296	6282	5793 e	8
Sammos	5706	6260	6367	6111 cde	6
Santos	5982	7396	5064	6147 cde	5
Sole	3816	5364	6158	5113 f	10
Tarzan	5059	5066	7833	5986 de	7
Zerberus	6149	5233	5633	5672 e	9
Foliar mean	5745 a	6287 a	6856 a	6296 y	
Both years mean					
KSH 3723	4894	5679	6602	5956 cde	7
KSH 3724	6534	6496	6436	6440 bc	3
Lemnos	6636	6680	7408	6878 b	2
Leonie	6844	7367	8254	7579 a	1
Merlin	5179	6018	5872	5697 def	8
Sammos	4668	5008	4936	4871 g	10
Santos	5499	6789	4861	6164 cd	4
Sole	5300	6153	6445	5975 cde	6
Tarzan	5588	5323	7405	6105 cd	5
Zerberus	5691	5288	4997	5262 fg	9
Foliar mean	5683 a	6080 a	6322 a	6093	

Means labeled with the same lowercase letter for same Cultivar or Foliar side-dressing average in each Year or Means group are not statistically different at $P > 0.05$ significance level.

differences of leaf structure or potential benefit from foliar uptake of organic growth stimulators in comparison with pure mineral fertilization, where organic growth stimulators are not present. In case of post-sown millet, buckwheat and sudan grass, Stipešević et al. (2010, 2011) found that biological foliar fertilization can be as effective as foliar fertilizers with mineral nutrients only. Ling and Silberbush (2002) also found no significant difference among different foliar fertilizers on maize growth.

Regarding the average of both years, there were no statistical differences of fresh and dry biomass between them, presumably that, in spite of slightly higher temperature for 2015, seemingly more favorable distribution of precipitation in 2016 provided a slightly higher biomass average.

Conclusion

The present study of the effects of sorghum cultivars and foliar side-dressing systems on post-harvest sown sorghum in Northeastern Croatia agro-environment showed that the highest biomass yield can be obtained with cultivar Leonie, followed by Lemnos, KSH 3724, Santos, KSH 3723, Merlin, Sammos, Sole, Tarzan and Zerberus. Foliar side-dressing with used liquid fertilizers showed relative trend of higher yields for all cultivars in comparison with cropping sorghum as post-harvest crop without any side-dressing. In more cases mineral foliar fertilizer showed trend of contributing toward higher biomass yield of sorghum than used biological foliar fertilizer.

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