Influence of Grazing Time and Herbicide Kill Time on Grain Yield of Sorghum in a No-Till System

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ABSTRACT

We evaluated the effect of length of fallow period after application of glyphosate herbicide to kill oats (*Avena sativa* L.) planted for grazing. We also evaluated grazing management practices on the subsequent emergence, growth and yield of grain sorghum (*Sorghum bicolor* (L.) Moench) planted for grain in a no-till system. Grazing increased soil resistance to penetration in the top 2 inches by 9% and increased availability of NO_3-N in the top 8 inches of soil significantly as the length of fallow period increased. The number of grain sorghum plants and their growth were reduced significantly when the fallow period was less than 20 days or greater than 40 days. When the fallow period was only 19 days, the NO_3-N concentration and grain sorghum stand was affected by the amount of oats stubble present. Grain yield was related to the number of plants that survived.

KEYWORDS

Soil compaction, oat winter pastures, fallow duration.

INTRODUCTION

The utilization of winter crops followed by the planting of summer crops is a common practice in agricultural and livestock production systems in Uruguay. The effect of grazing on the subsequent crop was studied by Devoto and Gonzáles (1999), who found that resistance to soil penetration in the top 2 inches increased significantly from 0.99 to 1.5 Mpa when the sheep stocking rate was increased from 24 to 73 lambs acre^{-1}. Díaz-Zorita *et al.* (2002) reported similar changes for sites used for grazing either with or without tillage.

When summer crops are established without tillage operations, it is common to have planting problems, which lead to reductions from 20% to 50% in grain production (Martino, 1994; Martino, 1998) and are associated with reduced plant survival and rate of crop growth. The biggest problems have been encountered in corn (*Zea mays* L.) and sunflower (*Helianthus annuus* L.), followed by grain sorghum and soybean (*Glycine max* (L.) Merr.) (Scarlato *et al.*, 2001).

The problems in the planting and growth of crops planted immediately after the harvest of another crop have been attributed to the presence of phytotoxic compounds liberated by the previous crop or generated during the decomposition of roots and stubble on the surface. Phytotoxic compounds are liberated directly with rainfall leaching of the residue, or indirectly as products and subproducts of microbial activity during the decomposition of the stubble. Phytotoxic potential lessens as the crop residues age, according to Martín *et al.* (1990).

The residues of oats, rye (*Secale cereale* (L.) , Swedish turnip (*Brassica na*pus L. var. napobrassica (L.) Rchb.) and colza (*Brassica napus* L. var. Napus) reduced the later growth of weeds for prolonged periods of time (Almeida *et al.*, 1985; cited by Floss, 2000). With oat residues, the soil remained free from grass and broadleaf weeds for 85 days. Kimber (1973) and Raimbault *et al.* (1991) found that the phytotoxic compounds produced by the residues of alfalfa (*Medicago sativa* L.), peas (*Pisum arvense* L.), oats, perennial ryegrass (*Lolium perenne* L.) and wheat (*Triticum aestivum* L.) occurred mainly in the first stages of decomposition. Acetic, propionic, and butyric acid, frequently associated with allelopathy, which occurs during the decomposition of wheat straw, increased gradually for 12 days and then declined (Tang and Waiss, 1978). The oat biomass showed allelopathic control on a number of plants, establishing an inhibiting effect directly or indirectly on plants and also on microorganisms (Floss, 2000). Roth *et al.* (2000) attributed the lower yield of wheat after grain sorghum to the presence of phototoxins. The negative effects were eliminated with tillage and with sorghum-fallow-wheat rotation. In both cases, the phytotoxic effect would be lessened by increasing the rate or time of decomposition. Evaluating leguminous plants and with rye as cover crops, Ross *et al.* (2001) quantified the phytotoxic

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effects on the number and growth of weeds during the subsequent fallow period. The effect was greater and more prolonged in low fertility soils.

Ernst *et al.* (2001) succeeded in improving the emergence and survival of crops planted without tillage in old pastures by lengthening the period between herbicide application and planting of the next crop. These authors found a greater content of water and NO_3-N in the soil and less resistance to penetration at the time of planting the summer crop when this fallow period exceeded 45 days. This resulted in a significant improvement in emergence and initial growth. The authors attributed these results to the reduced loss of water from the soil by transpiration and to the termination of the decomposition of roots and above ground residues, permitting the accumulation of nutrients and the reduction of phytotoxic compounds produced by the previous crop or during the period of decomposition.

The object of this study was to evaluate the effect of the date of herbicide application and the date of the end of grazing of oats on the planting, growth, and yield of grain sorghum in a sequence of oats-sorghum without tillage.

MATERIALS AND METHODS

The experiment was conducted in Uruguay (32 °S, 56 °W) on typical Brunosol Eutrico soil with 2.4% organic C and 15 ppm of phosphorus (Bray I) in the top 8 inches of soil. Rainfall between May and September was 93% higher than the historical average, with 27 inches falling during this period. The experimental area was planted with a sequence of crops without tillage beginning in 1997. On 8 March 2000, oats were planted; the grazing treatments imposed are shown in Table 1. After grazing, 29, 16 and 41 lbs acre^{-1}, of N was added as urea to the oats cover crop in treatments 1, 3, and 4, respectively.

On 28 August, five grazing treatments were imposed to the oats, which are shown in Table 2. On 29 September, after 34 days of the growth of the oats, treatment I employed grazing with 1492 lbs acre^{-1} of live-weight for 6 days (8952 lbs acre^{-1} in total). Grain sorghum (Pioneer 8586 hybrid) was planted on 21 November using a John Deere 750 direct planter. The distance between rows was 15 inches. The grain sorghum was harvested on 4 April, 2001

The quantity of oats dry matter at the time the glyphosate herbicide was applied was determined (Mannetje, 1978). Before the planting of the grain sorghum crop, soil penetrometer resistance was measured at two depths (0-2 inch and 2-4 inch), taking 30 random measurements per plot. The NO_3-N concentration and water content was measured at planting and at the V6 stage of grain sorghum, on 0-8 inch soil samples (28 Dec, 2000). The number of seedlings surviving 15 days after planting in 60 ft of row per plot (3 furrows of 20 ft) was counted. On 28 December, 30 plants per plot were taken at random and dry weight, height (inches), state of development using the Haun scale, and N concentration (Kjeldhal) were measured. At harvest, the number of ears meter^{-2}, the weight of a thousand grains, and the grain yield were quantified.

Table 1. Grazing date, grazing duration, and animal weight during each grazing period. Young bulls with an average weight of 880 lbs were used.

			Animal weight	
No.	Date	Duration	Daily	Total
		- days -	lbs acre^{-1} day^{-1}	lbs acre^{-1}
1	5/11	7	2141	14987
2	6/29	3	2890	8670
3	7/21	5	2105	10525
4	8/19	6	1998	11988

Table 2. Description of treatments.

	Treatment no.				
	I	II	III	IV	V
Date of last grazing	9/29	8/24	8/24	8/24	8/24
Days of oats growth before grazing	34	-	-	-	-
Days between last grazing and application of glyphosate	35	29	35	53	69
Date of glyphosate application	11/2	9/22	9/28	10/17	11/2
Days between herbicide application and sorghum-planting	19	59	53	35	19

Table 3. Rainfall (inches) between 24 August, 2000 and the blooming of grain sorghum.

	Treatment no.				
	I	II	III	IV	V
Until glyphosate application	9.7	4.4	4.4	6.7	9.7
Glyphosate application-seeding	1.0	6.3	6.3	3.9	1.0
10 days before seeding	1.0	1.0	1.0	1.0	1.0
10 days after seeding	2.6	2.6	2.6	2.6	2.6

The experiment design used was a completely randomized design with three replications. The size of the plot was 5382 ft. The results were analyzed using the GLM procedure of the Statistical Analysis Systems (SAS, 1996). Separation of measurements was done using the $LSD_{0.05}$.

RESULTS AND DISCUSSION

Table 3 shows the rainfall that occurred in different phases of the experimental period. Rainfall distribution ensured that water in the soil profile in all the treatments was recharged. The rainfall measured 10 days prior and 10 days after planting totaled 3.5 inches, so rainfall cannot be considered a limiting factor for planting conditions. During the growing season, rainfall exceeded crop demand.

Oats pasture

There was a significant relationship between the days of fallow and the concentration of NO_3-N in the first 8 inches of the soil profile (Fig. 1).

When the period of oats growth was increased from 29 to 69 days (treatments II to V), the herbicide application was made on an increasing quantity of oats dry matter, and consequently the residue went from 1026 to 4558 lbs acre^{-1} with a lower initial N concentration (2.4 and 1.4% of oats dry matter, respectively). In treatment I, on 29 September there was additional grazing, and 1277 lbs acre^{-1} of oats dry matter was consumed. The oats growth period of 47 days produced a similar quantity of residue than treatment IV (1606 and 2105 lbs acre^{-1}, respectively), but with 3.6% N concentration so that its lower concentration of NO_3-N at

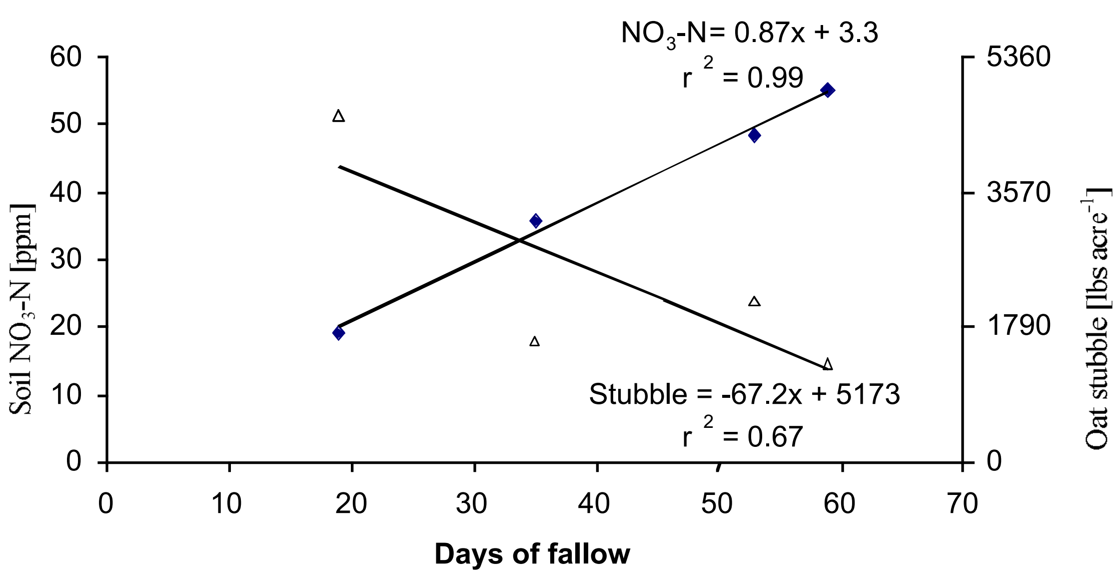

Fig.1. Effect of days of fallow on the quantity of oats stubble and NO3-N concentration in the soil profile at grain sorghum planting (treatments II, III, IV and V, only).

Table 4. Soil moisture (0 – 8 inches) and penetrometer soil resistance at time of grain sorghum planting.

	Treatment no.					
	I	II	III	IV	V	Avg
Soil moisture, %	21.1 a	23.0 a	23.1 a	22.0 a	22.1 a	22.2
Penetration resistance, kg cm^{-2}						
0 - 2 inches	2.27 a†	2.06 b	2.05 b	1.93 b	2.08 b	2.08 A‡
2 – 4 inches	2.09 a	1.88 b	1.83 b	1.78 b	1.92 b	1.90 B

† Treatment means followed by the same lower case letter are not significantly different based on $LSD_{0.05}$.

‡ Overall depth means were different based on $LSD_{0.05}$

planting would be explained by the shorter fallow period. Comparing treatments I and V with the same fallow time (19 days), the differences in NO_3-N at planting would be the result of the different quantities of oats stubble and concentrations of N. The results agree with those reported by Ernst (2000), Alvarez *et al.* (2001), and Ernst *et al.* (2001), who defined a minimum fallow time of 40 to 50 days to permit the decomposition of above ground residues and to accumulate N and water in the soil. In this case, treatments did not show significant differences in the soil moisture by rainfall occurring between 24 August and 21 November.

There were significant differences in resistance to soil penetration between the two depths that were evaluated (Table 4).

Resistance to penetration was 9% greater in the top inch of the soil profile, independent of the treatments (average 2.08 *vs*. 1.90 kg cm^{-2}) (Table 4). This profile of resistance to soil penetration is similar to that found by other authors following grazing. Treatment I significantly increased resistance to soil penetration at both depths that were evaluated. Given that there were no differences in soil moisture, differences must be attributed

Table 5. Number of grain sorghum plants 15 days after planting, availability of NO_3-N, plant dry matter, plant height, nitrogen content, N amount per plant, plant dry matter per acre and N uptake of grain sorghum at V6.

	Treatment no.				
Response variable	I	II	III	IV	V
Stand, plants ft^{-2}	172 b†	211 ab	216 a	174 b	128 c
Measurements taken at V6					
Soil NO_3-N (ppm)	4.4	6.1	6.2	6.9	4.8
Plant dry matter, g	6.9 a	9.7 a	10.1 a	6.4 a	3.6 b
Plant height, inches	21.5 a	25.2 a	24.9 a	22.0 a	16.5 b
N plant, %	2.6 b	3.3 a	3.2 a	3.0 a	3.2 a
N-amount, g plant^{-1}	0.18 b	0.32 a	0.32 a	0.19 b	0.12 c
Plant dry matter, lbs acre^{-1}	976 b	1707 a	1772 a	960 b	385 c
N uptake, lbs acre^{-1}	25.4 b	56.3 a	56.7 a	28.8 b	12.3 c

† Means within a row followed by the same letter are not significantly different based on $LSD_{0.05}$.

Table 6. Treatment effects on sorghum grain yield and yield components.

	Treatment no.				
	I	II	III	IV	V
Ears plants^{-1}	1.0 a	0.85 b	0.75 b	0.94 a	0.92 a
Ears yard^{-2}	19 a	20 a	18 a	18 a	13 b
Weight 1000 grains (oz)	0.74 ab	0.68 b	0.68 b	0.70 b	0.78 a
Grain yield, lbs acre^{-1}	4666 a	4746 a	4646 a	4571 a	3792 b

† Means within a row followed by the same letter are not significantly different based on $LSD_{0.05}$.

to the affect of additional 47 days of growth following grazing before planting. Although the effect of direct grazing has been recorded at greater depths than those evaluated in this study (Touchton *et al.*, 1989), the greatest effect occurred in the top depth of the soil profile.

GRAIN SORGHUM

Treatments II and III produced the same number of plants yard^{-2}, exceeding I and IV by 16% and V by 57% (Table 5).

At the V6 stage, grain sorghum crops had less growth per plant and per unit of surface in the treatment with longer growth time for oats and less time between the application of the herbicide and grain sorghum planting (treatment V). The effect on the grain sorghum dry matter production and N uptake was similar. On the other hand, treatment I, which showed the greatest soil penetrometer resistance in the top four inches of soil was intermediate, producing 34% more plants than treatment V, but 25% less than the best treatments (II and III). Unlike treatment V, it did not negatively affect individual growth or N uptake. Treatments I and IV did not differ from each other. The results showed a negative effect from a greater quantity of oats stubble combined with reduced fallow time on the planting and initial growth of grain sorghum. Given that moisture at planting and the rains that occurred during the ten days afterwards cannot be considered as limits for the planting process, and that the concentration of NO_3-N, although lower, was not below the critical level, the effects must be attributed to other factors, including the presence of phyto-toxicity. As is mentioned by Tang and Waiss (1978) and Floss (2000), the negative effects on the planting and growth of crops planted immediately after the death or the harvest of oats lessen with decomposition time and are directly related to the quantity of stubble that is present. On the other hand, in the treatment with five days of oats grazing (V), while there was increased soil penetrometer resistance compared to all the other treatments, which received four days of grazing, grain sorghum behaved similar to the treatment that left a similar quantity of oats stubble (IV). The only quantitative difference between these two systems was the concentration of NO_3-N in the top eight inches of soil at the time the grain sorghum panting, which might be explained by the reduced fallow period (19 days *vs*. 35 days, respectively).

The only treatment that negatively affected the yield of grain sorghum was number V (Table 6). Treatments I and IV succeeded in compensating for the lower number of initial plants with a greater number of ears per plant and greater grain weight. An excessive quantity of oats stubble combined with reduced fallow time negatively affected the planting, growth, and yield of the grain sorghum (V). While additional grazing (treatment I) reduced the number of plants meter^{-2}, it did not affect growth, which under conditions of high water availability allowed for problems with planting to be compensated. Under normal moisture conditions in which the possibilities of compensating for the lack of plants are less, treatments II and III with 50 to 60 days of fallow would permit the accumulation of water and N and optimize the planting process and the subsequent growth of the grain sorghum.

CONCLUSIONS

There was a negative relationship between days of fallow period and soil NO_3-N concentration in the top 8 inches of the soil. When the fallow period was only 19 days, NO_3-N concentration was reduced by increasing oat stubble. Grazing increased soil penetrometer resistance in the top 2 inches of soil, especially when grazing was close to grain sorghum planting. The emergence and initial grain sorghum growth was reduced by large amounts of oats stubble and a shorter fallow period. With this management, the grain yield was 816 lbs acre^{-1} less than with a fallow period of 35 to 50 days.

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