Effect of Mechanical Stress on Growth of Quackgrass (*Agropyron repens* (L.) Beauv.)

I. Effect of Treading Stress under Different Cutting Frequencies and Soil Compactions.

Akio HONGO and Yasuhiko OHE

Department of Grassland Science, Obihiro University of
Agriculture and Veterinary Medicine, Obihiro, Hokkaido 080.

Quackgrass is reported to colonize arable fields mostly by rhizome fragmentation caused by soil cultivation^{5,22)}, but rarely by seedling establishment. Once established in an arable field, quackgrass vigorously produces rhizomes. With no disturbance, parent plants distribute daughter shoots about one meter apart during the growing season¹⁰⁾. In actuality, however, they rarely grow at this rate because of the many stresses present such as crop competition, cutting by hoeing, or treading on by animals or farm machinery. Although there have been many studies on the effects of these first two factors^{6,7,9,17,23)}, little is known about the spreading ability of rhizomes affected by mechanical stresses in spite of the importance of this information to control of the weed^{2,13)}. The present study was designed to assess growth response of quackgrass to treading, one of many mechanical stresses, under different cutting frequencies and soil compactions.

1. Materials and Methods

The experiments were conducted twice in the field of Obihiro University, during April 28 to October 13, 1982 and during April 1 to October 1, 1983. Rhizome fragments 5-cm long and seeds were used in 1982 and 1983, respectively. These were collected from the same abandoned field.

Rhizomes or seeds were planted in plastic trays filled with vermiculite. Emerged shoots

or germinated seeds were transplanted into polyethylene pots (7.5 cm in diameter) containing soil. These plants were grown for 25 days in 1982 and 45 days in 1983 in an unheated greenhouse. Forty and 80 plants of almost the same size were selected in 1982 and 1983, respectively, and were transplanted into the field at 2 m intervals. Fertilizer containing 5 kg nitrogen, 9 kg phosphorus and 9 kg potassium per 10 are was applied prior to each transplanting.

In 1982, the experimental field was split into two main plots which were treated by treading stress: six-time treading at 20-day intervals and twice treading at 60-day intervals. In each main plot, 20 plants were separated at random into two groups, which were cut six times and twice, respectively. In 1983, the area of the experimental field was twice that in 1982. This field was also split into two main plots; one was treated by soil compaction and the other served as control. The same treatments were done in the two main plots in 1983. In both experiments, treading was done four times with a small concrete roller (80 kg weight). Soil compaction was done four times with the wheels of a large tractor (6.5 ton weight) only in 1983.

Shoot distribution was recorded on 1/25-scaled section papers at 20-day intervals and mean distance of total shoots from the planted center was measured. At each cutting time aerial shoots were clipped to leave stubble 5

Fig. 1. Penetration resistance of soil at various depths.

- : control and twice treading
- : control and six-time treading
- : compacted soil and twice treading
- : compacted soil and six-time treading

Fig. 2. Number and mean distance of aerial shoots from the planted center.

- : twice treading and twice cutting
- : twice treading and six-time cutting
- : six-time treading and twice cutting
- : six-time treading and six-time cutting
- ↓ : treading,] : significant difference ($p < 0.05$)¹⁹⁾

cm long and their dry weight was measured after drying for 3 days in a forced drought oven at 75°C. Distributed rhizomes were

sampled 24 weeks (1982) and 26 weeks (1983) after planting rhizomes and seeds, respectively, and their dry weight was also measured. In 1983, burial depths of the two longest rhizomes per plant were measured at about 10 cm intervals along the rhizome distribution. Their total length, and the diameter and internode length at a midpoint were also measured. Penetration resistances in the soil were measured with a soil penetrometer after the experiment in 1982.

2. Results

(1) Vertical distribution of penetration resistance in soil

Figure 1 shows the result of penetration resistance in the soil measured on October 2, 1982. Soil which was deeply compacted by the wheels of a large tractor had a penetration resistance of 12 kg/cm², compared with 4 kg/cm² at a 20 cm depth in the control area. Effect of the small roller was limited to the soil surface. Penetration resistance on the surface was 12 kg/cm² in control trodden six times compared with 7 kg/cm² in compacted soil trodden twice.

(2) Number of shoots and rhizomes

It was evident that shoot number was decreased by frequent cutting or treading in both years, but was slightly increased by soil compaction. Comparison of shoot number curves in 1982 showed appreciable differences between treatments 120 days after rhizome planting, followed by a period of rapid increase (Fig. 2). Mean shoot number per plant at the last sampling was 59 in six-time cuttings and 72 in twice cuttings when trodden six times, and 110 and 201, respectively, when trodden twice. In 1983, there was the same tendency of shoot number with respect to treading and cutting treatments as in 1982, decreasing by 87% in frequent treading and by 55% in frequent cutting compared with each lax treatment (Table 1). In contrast, soil compaction increased shoot number by 159% compared with control.

Table 1. Number of *Agropyron repens* shoots or rhizomes with tips remaining in soil.

Treatment		Shoots		Rhizomes	
Treading	Cutting	C ₀ *	C ₁	C ₀	C ₁
Six-time	Six-time	27	39	58	54
	Twice	31	72	77	90
Twice	Six-time	25	38	68	67
	Twice	57	74	137	178
Significant level**		39		53	

* : C₀ and C₁ represent control (no compaction) and compaction of soil, respectively.
** : Calculated by Q method¹⁹⁾ ($p < 0.05$).

Results in rhizome number were almost the same as those in shoot number. Frequent treading and cutting lowered rhizome number by 62% and 51%, respectively, whereas soil compaction increased it by 114% compared with control.

(3) Mean distance of total shoots from the planted center

Mean distance of total shoots was decreased by frequent treading or soil compaction, but was little affected by cutting treatment. Reduction in mean distance of total shoots was apparently greater in frequent treading (41~42 cm) than lax treading (50~53cm) in

Fig. 3. Frequency of distributed shoots per distance from the planted center.
C₀ and C₁ represent control and compacted soil, respectively, and T₂ and T₆ represent twice and six-time treading, respectively.

1982 (Fig. 2). The results in 1983 (Fig. 3) showed the same tendency, with comparable

Table 2. Dry matter production (g/plant) of aerial shoots and rhizomes in *Agropyron repens*.

Treatment		Aerial shoots		Rhizomes		Total		S/R* ratio	
Treading	Cutting	C ₀ **	C ₁	C ₀	C ₁	C ₀	C ₁	C ₀	C ₁
(A) Results in 1982									
Six-time	Six-time	44	—	36	—	80	—	1.2	—
	Twice	87	—	79	—	166	—	1.1	—
Twice	Six-time	166	—	57	—	173	—	2.0	—
	Twice	178	—	153	—	331	—	1.2	—
Significant level		82	—	62	—	96	—	—	—
(B) Results in 1983									
Six-time	Six-time	33	34	10	12	43	46	3.3	2.8
	Twice	41	67	19	30	60	97	2.2	2.2
Twice	Six-time	46	38	23	15	69	53	2.0	2.5
	Twice	82	96	22	59	104	155	3.7	1.6
Significant level***		39		16		47		—	

* : S and R represent shoot and rhizome, respectively.
** : C₀ and C₁ represent control (no compaction) and compaction of soil, respectively.
*** : Calculated by Q method¹⁹⁾ ($p < 0.05$).

values of 72% for frequent treading, 85% for frequent cutting, and 82% for soil compaction. These results were related with spatial patterns of distributed shoots. Less than 1% of the shoots distributed 40 cm apart from the planted center in compacted soil when trodden six time, whereas this figure was 14% in control when trodden twice (Fig. 3).

(4) Dry matter production

DM production per plant was also decreased by frequent treading, frequent cutting and compacted soil. In 1982, compared with lax treading and cutting, DM production was reduced by 24% in both frequent treatments, and by 50~52% in mixed frequent and lax treatments (Table 2). Results in 1983 showed similar reduction in DM production per plant, corresponding to 34% by frequent treading and cutting. In contrast, quackgrass produced significantly more DM in compacted soil than in control, with an increase rate of 127%. This increasing tendency was apparent especially in the twice cutting plot, where it was 154%.

(5) Distributed depth of rhizomes in soil

Distributed depth of rhizomes in soil was most affected by soil compaction and least affected by cutting and treading frequency. A diagram on the distributed depth of rhizomes in soil is shown Fig. 4, and results of burial depth, internode length and diameter of rhizomes are shown in Table 3. In control, mean value of the maximum depth per rhizome was 9.9cm and 4.7cm when trodden twice and six times, respectively, whereas it was 3.8cm and 3.6cm in compacted soil. A similar result was obtained in internode length. In contrary, there was little effect of treading frequency and soil compaction on rhizome diameter.

3. Discussion

In this study, soil compaction and treading were separately treated in order to assess the effect of treading apart from that of compacted soil on the growth of quackgrass. There

Table 3. Length and diameter of internode and depth of rhizomes of *Agropyron repens* in soil.

Treading	Length of internode (cm)		Diameter of internode (mm)		Depth of rhizome (cm)	
	C ₀ *	C ₁	C ₀	C ₁	C ₀	C ₁
Six-time	1.9	1.4	2.0	2.3	4.7	3.6
Twice	2.6	2.3	2.2	2.3	9.9	3.8
Significant level**	0.5		0.6		1.6	

* : C₀ and C₁ represent control (no compaction) and compaction of soil, respectively.

** : Calculated by Q method¹⁹⁾ ($p < 0.05$).

Fig. 4. Depth of rhizomes in soil per distance from the planted center.

C₀ and C₁ represent control and compacted soil, respectively, and T₂ and T₆ represent twice and six-time treading, respectively.

⬤ represents underground shoot.

have been many reports^{4,5)} on the growth response of crops to soil compaction induced by the wheels of a farm machinery, with decrease in length, weight and density of the root. It has also been reported that soil compaction affects not only penetration resistance but also bulk density^{1,14,20,24)}, moisture supply by capillary attraction^{18,21)}, oxygen supply and nutrient absorption³⁾. In this experiment, penetration resistance increased three times in compacted soil compared with in control. However, results contradictory to the above reports were obtained in the growth response of quackgrass affected by soil compaction: an increase in total DM production per plant of 127% and in shoot number of 114~159%, and a decrease in mean distance of total shoots of 88%. This tendency was

most apparent in total DM production and shoot number in compacted soil when cut twice. From the point of rhizome reproduction, increased shoot number compensated for reduction in spreading ability. Similar results have been reported by O'NEIL and CARROW^{15,16)} in *Poa pratensis*. In addition, JAFFE¹¹⁾ pointed out that a plant produces ethylene as a result of mechanical stress, which causes a reduction in longitudinal growth (*e.g.*, plant height or leaf length) but an increase in radial growth (*e.g.*, hypertrophy of the stem). In this study, depressed elongation of rhizomes accelerated shorter rhizome production. It seems therefore that more research is needed to determine the morphogenetic response and rhizome behaviour in compacted soil.

There was little difference between growth response of shoots from rhizome fragments in 1982 and that of seedlings in 1983 with respect to cutting, treading and soil compaction. In both years, frequent treading decreased total DM production by 49~65%, mean distance by 72~81%, and shoot number by 42~87%, compared with lax treading. Similarly, frequent cutting decreased by 50~51%, 85~98% and 51~62%, respectively, compared with lax cutting. When both treatments were applied frequently, greater reduction was observed as a result of interaction. Thus, decreased rate of growth by treading was the same as that by cutting. It has been reported that reduced growth by treading is due directly to the physical damage of aerial shoots^{1,4,20)} and indirectly to physiological reduction of photosynthesis on the leaf blade¹²⁾. The present result suggests that reduced growth is related to direct damage because of low tolerance to treading.

Allowing for these results, the effective control of quackgrass would be attainable by periodical weeding. However, different growth response may also be obtained under different rate of soil compaction, different frequency of treading, or different soil type. Further study is therefore necessary to elucidate the

involvement of these factors in the ecology of quackgrass.

4. Summary

Growth of shoots from rhizome fragments of quackgrass was investigated in relation to cuttings and treadings during April to October, 1982, and growth of seedlings was also investigated in relation to cuttings, treadings and soil compaction in 1983. Cuttings or treadings with a small roller (80-kg weight) were conducted twice (60-day intervals) or six times (20-day intervals), respectively. Soil was compacted with the wheels of a large tractor (6.5-ton weight) before the experiment in 1983.

1) Penetration resistance in compacted soil increased three times as much as that in the control plot between 0 and 20 cm depth. Treading effect was observed only between 0 and 5 cm depth.

2) There was no difference between growth of shoots from rhizome fragments in 1982 and that of seedlings in 1983 for the above three treatments.

3) Total DM production per plant, mean distance of distributed shoots, and shoot number were decreased 49~65%, 72~81% and 42~87%, respectively, with increased treadings, and decreased 50~51%, 85~98% and 51~62%, respectively, with increased cuttings.

4) Mean distance decreased to 82%, while total DM production and shoot number increased to 127% and 114~159%, respectively, in compacted soil.

5) Depth of rhizomes in soil was 9.9 cm in control soil, while 3.6~4.7 cm in plots treated by treading or soil compaction.

6) It was suggested that rhizomes of quackgrass respond to treading stress by decreasing the breadth of their spreading and by increasing the number of shorter rhizomes produced.

Acknowledgements: We are grateful for

the valuable comments of Professors K. FUKUNAGA, T. SHIMADA and Y. MINO of Obihiro University.

References

- 1) BARLEY, K. P.: Soil Sci. **96**, 175~180 (1963).
- 2) BYLTERUD, A.: Weed Res. **5**, 169~180 (1965).
- 3) CASTILLO, S. R., R. H. DOWDY, J. M. BRADFORD and W. F. LARSON: Agron. J. **74**, 526~530 (1982).
- 4) EGARA, K., J. NAKANO and T. KANNO: Bull. Shikoku Agric. Exp. Stn. **25**, 35~56 (1974). (in Japanese with English Summary).
- 5) GRIMES, D. W., W. R. SHEESLEY and P. L. WILEY: Agron. J. **70**, 955~958 (1979).
- 6) HÅKANSSON, S.: Landbrhogsk. Annlr. **34**, 3~29 (1968).
- 7) HÅKANSSON, S.: Landbrhogsk. Annlr. **35**, 61~78 (1969).
- 8) HIRAKI, Y. and Y. OTA: Plant & Cell Physiol. **16**, 185~189 (1975).
- 9) HOFMAN, T. B. and G. C. ENNIK: Neth. J. Agr. Sci. **30**, 275~283 (1982).
- 10) HONGO, A. and S. IWAHASHI: Weed Res. Japan **27**, 98~102 (1982). (in Japanese with English Summary).
- 11) JAFFE, M. J.: Planta **114**, 143~157 (1973).
- 12) KUBO, H. and H. AKIYAMA: Bull. Natl. Grassl. Res. Inst. **10**, 15~22 (1977). (in Japanese with English Summary).
- 13) MUELLER-WARRANT, G. W. and D. W. KOCH: Agron. J. **72**, 884~889 (1980).
- 14) OHTOMO, K., N. FUGIMOTO and Y. MINO: Res. Bul. Obihiro Univ. **11**, 107~112 (1978). (in Japanese with English Summary).
- 15) O'NEIL, K. J. and R. N. CARROW: Agron. J. **74**, 933~936 (1982).
- 16) O'NEIL, K. J. and R. N. CARROW: Agron. J. **75**, 177~180 (1983).
- 17) RIOUX, R.: Can. J. Plant Sci. **62**, 183~188 (1982).
- 18) RUSSELL, R. S.: Plant Root System. McGraw-Hill Book Co., London, 143~168 (1977).
- 19) SNEDECOR, G. W. and W. G. COCHRAN: Statistical Methods (6th ed.). Iowa State Univ. Press, Ames, 271~275 (1967).
- 20) TAKIJIMA, Y., H. SAKUMA: Bull. Nat. Inst. Agr. Sci. Series B **21**, 255~328 (1971). (in Japanese with English Summary).
- 21) TAYLOR, H. M. and H. R. GARDNER: Soil Sci. **91**, 280~288 (1963).
- 22) WERNER, P. A. and R. RIOUX: Can. J. Plant Sci. **27**, 98~102 (1982).
- 23) WILLIAMS, E. D.: Weed Res. **17**, 69~76 (1977).
- 24) ZIMMERMAN, R. P. and L. T. KARDOS: Soil Sci. **91**, 280~288 (1961).

(Received June 15, 1985)

シバムギ (*Agropyron repens* (L.) Beauv.) の

生長におよぼす機械的刺激の影響

I. 刈り取り頻度と土壌の締め固め処理が異なる条件における踏圧の影響

本江昭夫・大江康彦 帯広畜産大学草地学科

摘 要

1982年4月~10月に、地下茎から採った苗条を用いて、刈り取り、踏圧がシバムギの生長におよぼす影響を調査した。さらに、1983年4月~10月に、種子からの稚苗を用い、土壌の締め固め処理の異なる条件において、刈り取り、踏圧の影響を調査した。刈り取りと80kgの小型ローラーによる踏圧はそれぞれ2回(60日間隔)、6回(20日間隔)とし、また土壌の締め固め処理は1983年の稚苗植付前に6.5tの大型車の車輪により行った。

1) 土壌の締め固め処理により土壌中20cmの深さまで貫入抵抗は増大し、対照区の約3倍になった。踏圧の影響は0~5cmでのみ認められた(Fig. 1)。

- 2) 3種類の処理に対して、1982年の地下茎からの苗条の生長と1983年の稚苗の生長との間に差は認められなかった (Fig. 2, Table 1)。
- 3) 踏圧回数が増えると、個体あたり総乾物生産量、苗条の植付位置からの平均距離、苗条数はそれぞれ49~65%、72~81%、42~87%に減少し、刈り取り回数が増えると、それぞれ50~51%、85~98%、51~62%に減少した (Fig. 2, Table 2)。
- 4) 対照区に比較して土壌の締め固め処理区では、苗条の平均距離は82%と減少したが、個体あたり総乾物生産量、苗条数はそれぞれ127%、114~159%に増加した。
- 5) 土壌中における地下茎の深度は対照区では9.9cmであったが、踏圧や土壌の締め固め処理を行った区では3.6~4.7cmと浅くなった (Fig. 4)。
- 6) このような結果から、シバムギ地下茎は踏圧刺激に対して、平面上に拡散する能力を抑制させるが、逆に、土壌中の浅い部分における短い地下茎の生産を増大させることが示唆された。