CORN YIELD AFFECTED BY WHEEL COMPACTION IN A DRY YEAR

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Soil structural damage caused by machinery wheels in a relatively dry year and its effect on the production of corn were studied in a field experiment during the year 1977. The treatments used were 1, 5, 10 and 15 passes each with vehicles having tire contact pressures of 31.4, 41.2 and 61.8 kPa. The results showed dry plant yields of 10 500 kg/ha for zero traffic plots compared to the maximum values of 12 500 kg/ha in the moderately compacted plots. In the heavily compacted plots, the values were 9000 to 9700 kg/ha. The yield results correlated well with the dry density of the compacted topsoil.

INTRODUCTION

In recent years, the effects on soil of off-road machinery traffic have been documented extensively (Soane 1970; Chancellor 1971; Davies et al. 1973; Amir et al. 1976; Raghavan et al. 1975, 1976). The changes in soil conditions caused by traffic can have considerable effects on the performance of crops grown (Phillips and Kirkham 1962; Feldman and Domier 1970; Eavis 1970; Taylor 1971; Saini and Lantagne 1974; Morris 1975; Voorhees et al. 1975). In these studies, marked reductions in yields of potatoes, wheat and corn were attributed to soil compaction.

A study quantifying the effect of contact pressure and the number of wheel passes on plant production was carried out by Raghavan and McKyes (1977). It was shown in this experiment that yield reductions of up to 50% could occur in heavily compacted plots. Yield values were highest in zero-traffic plots and averaged 16 000 kg/ha. It is recognized that yield reductions can be affected also by changes in weather conditions from one year to another. To find these changes, the experiment of 1976 was repeated in 1977. The experiment consisted of various plots of silage corn subjected to different traffic treatments. The objectives were:

(a) To quantify compaction damage.
(b) To determine a statistical model for plant yield in the soil studied as a function of the traffic variables or of the soil dry densities.

EXPERIMENTAL METHODS

A randomized complete-block experiment was established on a subdrained field of Ste. Rosalie clay, a chloritic-illitic soil having about 80% clay particles by weight. There were four replications of 12 treatments, consisting of 1, 5, 10 and 15 passes of tractors having measured wheel contact pressures of 31.4, 41.2 and 61.8 kPa. The control plots had a zero traffic treatment.

Before the traffic treatments, the field was prepared for seeding by plowing, disc harrowing, fertilizing and subsequent rotary tilling to a depth of 20 cm. Fertilizer and herbicides were applied at the rates of 450 kg/ha of 5-20-20 N-P-K, 2.3 kg/ha of atrazine and 5.7 L/ha of Lasso, respectively. After the completion of the traffic treatments, Co-op S265 silage corn was hand-seeded, with care being taken so as not to apply additional traffic on the plots. Two seeds were planted per hole to assure a uniformly distributed plant population. Thinning of duplicate plants was carried out in all the plots after 3 wk, followed by an application of 340 kg/ha of postemergence ammonium nitrate (total nitrogen 34%, ammonium nitrate 17%, nitrate nitrogen 17%).

Over the course of the growing season, measurements of both crop growth and soil densities were made, the latter being effected using a gamma ray density probe at 5-cm depth increments of 20 cm. In addition, soil moisture contents were taken gravimetrically at different depths. These were used subsequently to calculate dry bulk densities from the wet densities measured at
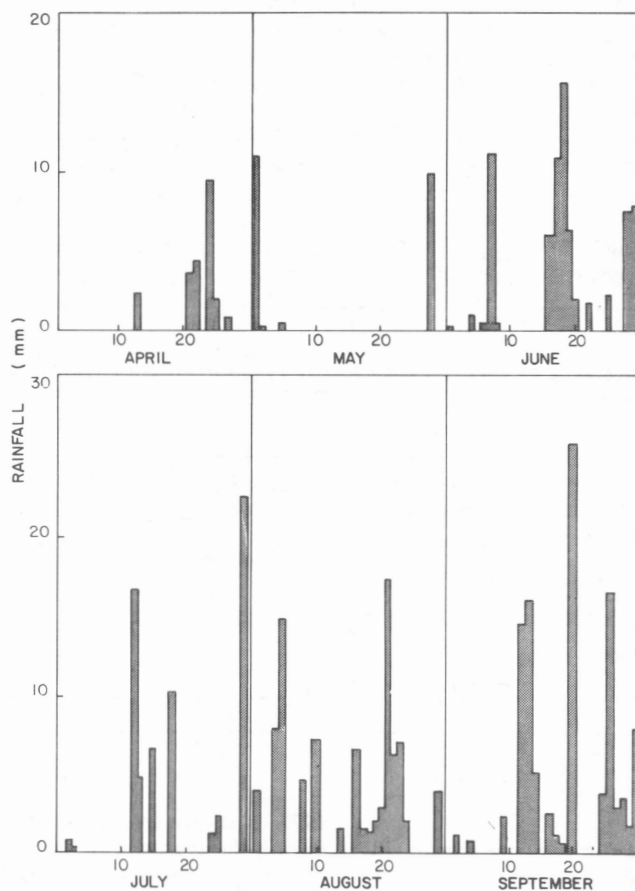

Figure 1. Rainfall measured at Macdonald College, 1977.

TABLE I. MODELS FOR YIELDS PREDICTED FROM CONTACT PRESSURE

a. Plant yield (kg/ha)

Source	df	Sum of squares	Mean square	F	Prob. $>F$
Regression	2	47 374 564	23 687 282	6.24	0.0037
Error	53	201 287 298	3 797 874		
Total	55	248 661 862			

	B value	SE	Type II SS	F	Prob. $>F$	R value
Intercept	10394					
np	9.951	2.822	47 224 680	12.43	0.0009	0.44
np^2	−0.011 27	0.003 33	43 567 309	11.47	0.0013	

b. Ear yield (kg/ha)

Source	df	Sum of squares	Mean square	F	Prob. $>F$
Regression	2	8 162 479	4 081 240	2.11	0.1315
Error	53	102 582 062	1 935 511		
Total	55	110 744 541			

	B value	SE	Type II SS	F	Prob. $>F$	R value
Intercept	6379					
np	3.974	2.015	7 531 349	3.89	0.0538	0.27
np^2	−0.004 87	0.002 38	8 131 218	4.20	0.0454	

TABLE II. MODEL FOR PLANT YIELD PREDICTED FROM DRY DENSITY

Source	df	Sum of squares	Mean square	F	Prob. $>F$
Regression	2	49 151 675	24 575 837	6.53	0.0029
Error	53	199 510 188	3 764 343		
Total	55	248 661 863			

	B value	SE	Type II SS	F	Prob. $>F$	R value
Intercept	−216270					
Density	438.8	166.4	26 184 115	6.96	0.0109	0.44
Density^2	−0.2107	0.0821	24 784 453	6.58	0.0132	

Figure 2. Variation of plant and ear yield with contact pressure.

various depths.

At the end of the growing season, the crop was hand-harvested with every alternate plant being cut from the middle row of the plot, and the total plant weight taken. A 1-kg sample was chopped and dried to determine the plant moisture content from which dry plant yield was calculated. Subsequently, the remaining plants were harvested, the mass of ears taken and ear moisture content and ear yield were calculated as before. The yield data were analyzed statistically as a function of traffic contact pressure, number of passes and soil dry density in order to determine the effects of the traffic treatments on plant production.

RESULTS

The daily rainfall measured at Macdonald College from May to October, 1977, is shown in Fig. 1. The total rainfall during the season was 360 mm, which was 100 mm less than the seasonal average for the area. Also, the distribution of rainfall in time was very irregular as can be seen in the figure.

In the analysis of yield results, several mathematical models were tried in the attempt to establish plant production parameters as a function of traffic treatments. Plant growth was found to be a function fo the machine-to-ground contact pressure and the square of the contact pressure as shown below:

$$Y = B_0 + B_1 (np) + B_2 (np)^2 \qquad \ldots \ldots \ldots \ (1)$$

where, Y is the plant ;yield in kg/ha and np is the product of contact pressure and number of passes in kPa. The coefficients B_0, B_1 and B_2 are listed along with their F values and pr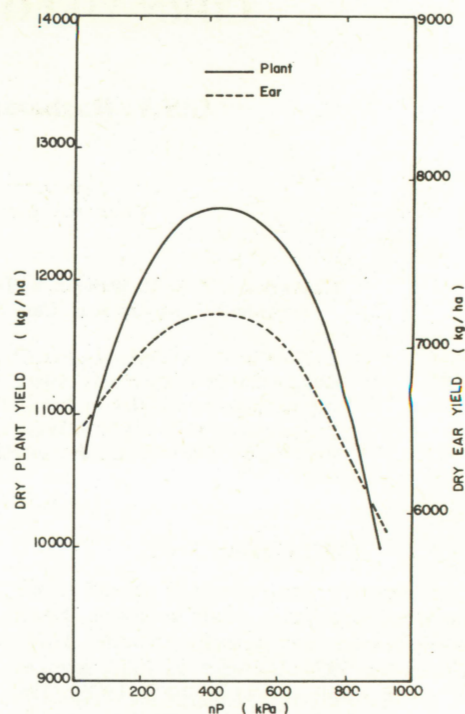obability levels in Table I, for both plant and ear yields. The relationship between plan and ear yields and the production np obtained from the models are shown graphically in Fig. 2. From this figure, it is seen that the maximum yield was obtained in the plots with values of the product np of about 500 kPa, whereas considerable yield reductions were observed at both higher and lower contact pressures. As np was increased to 900 kPa, the reduction in plant yield was 28% and the reduction in ear yield was 20%. Similarly, for an np value of 50 kPa, corresponding reductions were 14% and 8%. Since increases in contact pressure result in increases in dry density, the analysis was extended to include the effect of increasing dry density on plant yields. Table II shows the estimates of the intercept and the coefficients of density for density values averaged from readings taken at 5-cm intervals from depths of 5-20 cm. The model itself is given by:

$$Y_p = -216270 + 438.8\,(\gamma) - 0.2107\,(\gamma^2) \ldots (2)$$

where Y_p is the dry plant yield in kg/ha and γ is the dry bulk density of soil in kg/m$_3$ between the depths of 5 and 20 cm. Figure 3 shows the plot of dry plant yield versus dry density.

DISCUSSION

The corn growth experiment, based on a randomized block design with 13 treatments and four replications, indicated that in a dry year, there was an increase in plant and ear yield with increasing contact pressure and dry density up to a peak of 500 kPa and 1050 kg/m$_3$, respectively, which would be approximately equivalent to 10
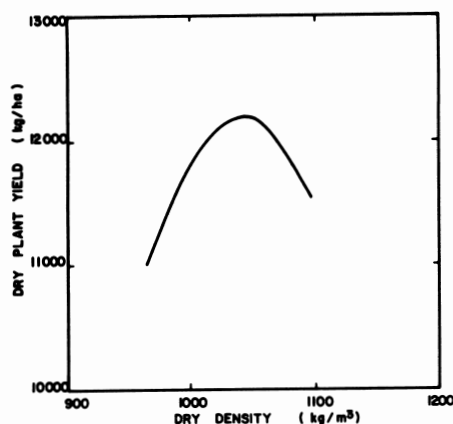
Figure 3. Variation of plant yield with dry density.

passes of a tractor having a mass of 3500 kg. These results are explained by the fact that in a dry year, water availability to the plants in uncompacted plots are poor compared to the moderately compacted plots. However, when compaction damage was heavy, the growth of the plants was restricted by high root penetration resistance of the soil, insufficient water availability and resulting reductions in nutrient uptake. The results from similar studies in a wetter growing season (Raghaven and McKyes 1977) showed that higher yields are possible in relatively less dense soils, as loose as 800 kg/m_3 dry bulk density, because more water is available despite the reduced water retention of loose soil at moderate moisture stress levels. Therefore, it is evident that when the weather conditions are abnormally dry, a certain amount of machinery traffic on a field can be beneficial. Further studies are required to determine the effect of each of the soil atmosphere properties on plant production.

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