THE USE OF A NON-IONIC SURFACTANT TO ALLEVIATE THE EFFECTS OF COMPACTED SOIL ON CORN (ZEA MAYS) YIELD AND ROOT GROWTH

Ernest H. Brumbaugh[1] (correspondence), Michael Petersen[2]

[1]Access Business Group International, 7575 Fulton Street East, Ada, Michigan, 49355, USA
[2]Natural Resources Conservation Service, United States Department of Agriculture, Greeley, Colorado, 80631, USA

Sixth International Symposium on Adjuvants for Agrochemicals – 2001 Amsterdam, Netherlands

SUMMARY

The use of a non-ionic surfactant applied to soil has been shown to increase corn root growth and yield at statistically significant levels. The test site was an irrigated field in Eastern Colorado, USA, composed of a sandy loam surface layer with a sandy clay loam subsoil that forms a compacted zone 8-15 in. beneath the soil surface. In a four year, two site study, application of APSA-80™, a non-ionic surfactant, applied at rates of 15, 30 and 45 oz/acre resulted in significantly increased root depth and crop yield. Corn root depth measured at 90% root volume increased 25-56%, and corn yield increased 13-17% depending on APSA-80™ use rate. Inter-row ripping, used one year on half of each surfactant plot, did not result in increased yield or root depth either the year the plot was ripped or the following two years.

Key words: soil compaction, non-ionic surfactant, corn (Zea mays) root growth

INTRODUCTION

Soil compaction caused by mechanised farming has long been recognized as negatively affecting crop yield in corn and many other crops (1, 3, 4, 5, 6). Soil compaction increases soil bulk density resulting in soil with a lower pore volume (1, 3, 4). Lower pore volume results in lower water and air holding capacity of the soil (1). Compacted soil also has a lower hydraulic conductivity resulting in slower movement of water through the soil profile (1, 2, 4). A compacted soil layer can make the plow layer wetter resulting in later planting, increased moisture stress on the crop and greater soil denitrification (1). Compacted soil reduces root growth by increasing the pressure needed to penetrate the compacted layer beyond the capability of the crop root to penetrate the soil (1, 3, 4). A compacted soil can increase soil carbon loss to the atmosphere (7).

Soil compaction in the subsoil layer is proportional to total axle load of machinery used in the field and is not removed by plowing or freeze-thaw cycles (1, 3, 4). Increased farm mechanisation, larger farm equipment, monoculture agriculture and increased cropping have all resulted in greater soil compaction (1, 3, 4, 6). In some states up to 95% of land used in corn production is compacted (5). Once compacted, cultivated soil will remain compacted for many years (3, 6).

Farmers have used various methods of alleviating soil compaction below the plow layer. These include reducing field traffic, limiting traffic to certain rows (controlled traffic), staying out of the field when it is wet and the use of subsoiling techniques such as inter-row ripping and subsoiling (deep ripping up to 30-36 in.) (1, 4). Sub-soiling can improve crop yield by breaking up the compacted layers but it must be done under the proper conditions and does result in loss of soil moisture (1, 4). Too much soil moisture during the subsoiling rocedure can increase soil compaction (1, 4).

Surfactants both lower the surface tension of water and decrease the contact angle of water to the soil particles (8,9). Soil moisture tension, which is proportional to the amount of work required for a root to extract moisture from the soil, is proportional to the product of the surface tension and the cosine of the soil:water contact angle (11). The combined effect of a surfactant will lower the surface tension and the soil:water contact angle having a beneficial effect on soil moisture tension depending on soil type and soil:water contact angle (11).

Surfactants have been shown to increase water infiltration into the soil, seedling germination and establishment, and to decrease soil erosion on "hard to wet" soils (9, 10). Surfactant soil treatments have also been reported to increase crop yield in compacted soils (12).

Soil treatments should, ideally, provide a beneficial effect but not accumulate in the soil. Biodegradable surfactants are readily consumed by bacteria in the soil and would not be expected to bioaccumulate. The product used in this paper has been shown to be such a surfactant (13).

MATERIALS AND METHODS

This study was conducted from 1997 to 2000 at the Irrigation Research Foundation (IRF), 40161 Highway 59, Yuma County, Colorado, USA, 80759. Soil at the IRF is a Haxtun sandy loam soil with two layers of sandy clay loam 6-10 inches and 10-18 inches beneath the sandy loam layer. Data on the soil series at the IRF is shown in Table 1.

TABLE 1. Soil Series Description
Haxtun Sandy Loam

Depth[a] in.	Texture[b]	pH
0-6	sandy loam	6.8
6-10	sandy clay loam	7.3
10-18	sandy clay loam	7.3
18-23	sandy loam	7.2
23-28	silty clay loam	7.0
28-41	silty clay	7.0

[a] Larson, R. 1976. Soil Survey of Yuma County, Colorado, USA

[b] United States Department of Agriculture soil texture nomenclature

Two irrigated fields at the IRF were used in this study. The first field used in 1997 had a compacted layer 8-15 in. beneath the soil surface. The second field, used in 1998-2000, had a compacted layer 10-15 in. beneath the soil surface. Corn was planted in the spring and soil treatments applied shortly after planting by broadcast spraying diluted product on the soil surface. Test plots were 20 x 100 feet in 1997 and 20 x 150 feet in 1998-2000. Each plot was planted in eight rows, on 30 in. centers, of corn with target populations of 28,000 plants per acre. Herbicides were applied both pre- and postemergent. The plots were a part of a 160 acre field with center pivot overhead irrigation. Irrigation water was applied to supplement natural rain as needed as determined by moisture tensiometers in the field. Fertilizer was applied as recommended by soil analysis. All treatments received the same fertilizer and irrigation levels. Agronomic practices used in each plot over the four years of this study are shown in Table 2.

Soil treatments in this study consisted of APSA-80™, applied at 15, 30 and 45 oz/acre in 8 gallons of water per acre. APSA-80™ , Access Business Group International, LLC, Ada, Michigan, is an 80% active non-ionic surfactant composed of a nonyl phenol ethoxylate, C9 nonyl phenol, 9.5 EO, and a tall oil fatty acid.

TABLE 2. Agronomic Practices

Parameter	Year			
	1997	1998	1999	2000
Corn Variety	Pioneer 3514	Pioneer 33A14	Novartis 4640	Novartis 6423
Planting Date	May 4	May 15	May 11	May 6
Fertiliser (lb N/a)	294	214	281	234
APSA-80™ Application Date	May 17	July 3	May 15	May 19
Herbicide Rate	Fulltime[a] 3 qt/acre	Tough - 1 pt/a Basis Gold 14 oz/a	Bicep Lite 2 qt/a	Roundup Ultra[b] 32 oz/a Fulltime 3 qt/a
Water Usage				
Rain	11.8 in.	11.0 in.	9.1 in.	10.3 in.
Irrigation	14.8 in.	13.5 in.	15.9 in.	15.2 in.
Total	26.6 in.	24.5 in.	25.0 in.	25.5 in.
Harvest Date	Nov. 14	Nov. 24	Nov. 2	Oct. 17

[a] Applied postemergent with 1 pt/acre COC + 9.3 1 gal/acre UAN(32-0-0)

[b] Applied postemergent with 17 lb/acre Ammonium Sulfate

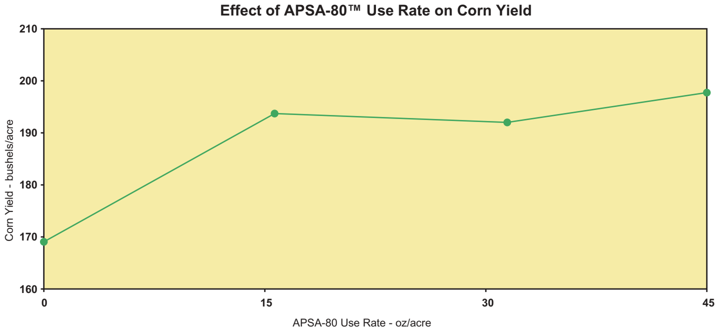
Test plots were evaluated for crop yield and root development. Root depth analysis was undertaken by digging a 4.5 foot deep pit in the field with a backhoe. Root evaluations were done visually with the use of a 1x1 in gridded clear plastic template, 20x30 in. Yield data was determined using a John Deere 6600 with a DMC Combine equipped with Calcu-dri and Weightronix. In 1998 the south four rows of the eight row plots were inter-row ripped to a depth of 12 in. All data was analysed using Analysis of Variance. Statistical significance was determined using the Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Four years of corn yield data is shown in Table 3 and three years of corn root depth-volume data in Table 4. The use of APSA-80™, at all rates tested, resulted in significantly increased yield when compared to the untreated control plot. The average yields were 169.2, 192.1, 190.2 and 197.6 bushels/acre (bu/a) for the untreated control and 15, 30 and 45 oz/acre APSA-80™ rates respectively. All rates of APSA-80™ increased yield over the untreated control at a 90% confidence level. The 15 and 45 oz/acre rates of APSA-80™ increased yield compared to the control at a 95% confidence level. The 45 oz/acre APSA-80™ rate was only run in 1998 and 1999.

TABLE 3. Effect of APSA-80™ Use Rate on Corn Yield

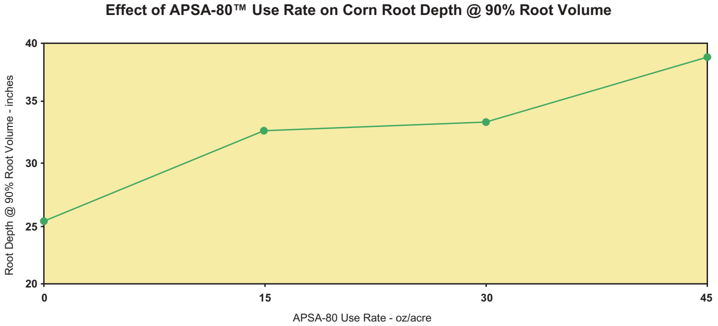
APSA-80™ Use rate (oz/a)	1997	1998	1999	2000	Average	DMRT	Percent Increase
	Corn Yield (bushels/acre)						
0	142	194.7	179.9	160.3	169.2	b	
15	184	200.8	192.8	190.9	192.1	a	+14.2%
30	205	196.4	195.7	163.5	190.2	a	+13.2%
45		199	196.1		197.6	a	+17.0%
	DMRT (0.05) 2 = 21.95						
	DMRT (0.10) 2 = 17.6						



Corn root depth measurements were taken from 1997-99 growing seasons. The measurements in 2000 were delayed due to a November freeze-up of the surface 12 in. of soil. Measurements will be taken in the spring of 2001 and are unavailable for this paper. Corn root depth at 90% root volume, (the volume of roots designated as the effective rooting zone), is shown in Table 4. All three APSA-80™ use rates show greater root depth at 90% root volume when compared to the untreated control. The average root depth at 90% root volume is 25.5, 32.5, 33.2 and 38.7 inches for the untreated control, 15, 30 and 45 oz/acre APSA-80™ rates respectively. All APSA-80™ rates were significantly different from the control at the 95% confidence level. It appears significant to note that as the APSA-80™ product has been applied over the course of this experiment, that the highest rate of APSA-80™ is causing the roots to drive deeper into the soil when compared to the untreated control.

TABLE 4. Effect of APSA-80™ Use Rate on Corn Root Depth At 90% Corn Root Volume

ASPA-80™ Use rate (oz/a)	1997	1998	1999	Average	DMRT	Percent Increase
	Corn Root Depth at 90% Root Volume (inches)					
0	24.5	25.5	26.4	25.5	b	
15	25.0	37.4	35	32.5	a	27.5%
30	33.7	35	31.0	33.2	a	30.1%
45		44.4	33.0	38.7	a	51.7%
	DMRT (0.05) 2 = 6.93					



Inter-row ripping was used on one half of each APSA-80™ test plot in 1998. The effect of inter-row ripping on crop yield was measured in 1998 and each subsequent year, although the plots were not ripped in 1999 or 2000. The data is shown in Table 5. Inter-row ripping did not increase crop yields on plots treated with APSA-80™.

TABLE 5. Effect of Inter-Row Ripping on Corn Yield

ASPA-80™ Use rate (oz/a)	1998	1999	2000		DMRT
	Ripped – Corn Yield (bushels/acre)				
15	200.3	190.8	190.8		
30	195.6	197.2	190.8		
45	190.8	163.8	151.0		
Average				186.0	a
	Not Ripped – Corn Yield (bushels/acre)				
15	206.7	194.0	197.2		
30	200.3	194.0	160.6		
45	195.6	201.9	157.4		
Average				189.2	a
	DMRT (0.05) 2 = 16.3				

CONCLUSIONS

The data shows that the use of a non-ionic surfactant, APSA-80™, applied to the soil significantly increased the depth and volume of corn root growth. Increased corn root growth should supply the corn plant with more water and nutrients from the soil, which should improve crop yield. The data also shows that the use of APSA-80™ increased corn yield significantly. Inter-row ripping did not affect corn yield when used on soil already treated with APSA-80™.

The use of APSA-80™ is a cost-effective method of dealing with effects of soil compaction. At suggested retail, the APSA-80™ treatments cost from $2.70 - $8.10 US per acre. Yield increases in this paper show a net return from use of APSA-80 of $45.80, $42.00 and $56.80 for the 15 oz/a, 30 oz/a and 45 oz/a rates of APSA-80™ respectively based on the currently depressed corn prices of $2.00/bushel. Net pay back less product cost is 16.0, 6.8 and 6.0:1 for the three APSA-80™ rates respectively.

It is assumed that the deeper root growth observed in the APSA-80™ plots would result in greater extraction of nutrients by the corn plant from a deeper soil depth. If this is the case then there should be a decrease in the requirement for supplemental nitrogen application as less nitrogen is being lost to the corn plant through percolation in the soil. In order to more fully ascertain the accuracy of this assumption soil samples for nitrogen analysis will be taken from the 24-33 in and 33-48 in. depths during the 2001 growing season.

REFERENCES

1. Soil Compaction: Causes, Effects and Control, Univ. of Minn. Extension Service, Swan, J.B., Moncreif, J.F., Vorhees, W.B., 1994.
2. Soil compaction and Drainage, Ohio State Univ. Extension Bulletin AEX-301.
3. Sizing Up Soil Compaction, Bauder, J.W., Montana State Univ. Extension Service.
4. Managing Soil Compaction, Petersen, M.L., Colorado State University Cooperative Extension #0.519.
5. Robertson, L.S., Michigan State University in “Managing Soil Compaction”, Butler Cat Bulletin.
6. Vorhees, W.B.; Horn, R., van den Akker, J.J.H., and Arvidsson, J. (eds.) 2000: “Subsoil Compaction: Distribution, Processes and Consequences, Advances in Geoecology 32” Internation Union of Soil Science.
7. Albrecht, William. 1938: pp.347-360 “US Department of Agriculture, Soils and Men, Yearbook of Agriculture” University of Missouri.
8. Letey, J.; Moldenhauer, W.C. (Ed.) 1975: “Soil Conditioners” Soil Science Society of America, Madison.
9. Osborn, J., Letey, J., DeDano, L.F., Terry, E. 1967: Ecology 48:494-497.
10. Osborn, J.F., Letey, J., Valoras, N. 1969: Calif. Agric. 23:6-8.
11. Hanks, R.J., Ashcroft, G.L. 1980: “Applied Soil Physics” Springer-Verlag, New York.
12. McCauley, G. 1993: Agron. J. 85(1): 17-21.
13. Hughes, A.I., Fisher, J.J., Brumbaugh, E.H. 1998: Alkylphenols & Alkylphenol Ethoxylates Rev. 1:17-22.

This article has been published in the ISAA 2001 Proceedings on Adjuvants for Agrochemicals. This book can be purchased from SURfaPLUS Company (info@surfaplus.com).

ACCESS
BUSINESS
GROUP