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Assessment of a Large Subsurface Controlled Drainage and Irrigation System: II. Corn Performance

Michael Aide*, Indi Braden, Neil Hermann, David Mauk, Wesley Mueller, Sven Svenson, and Julie Weathers

Southeast Missouri State University, 1 University Plaza, Cape Girardeau, MO 63701
*Corresponding Author – mtaide@semo.edu

Abstract: *Controlled subsurface drainage irrigation systems have been designed to promote agronomic production by optimizing water availability. In a previous manuscript we described the design of a 40 ha controlled subsurface drainage irrigation system, the soil resource and indicated the soil water properties. In this manuscript we describe the performance of corn (*Zea mays *L.) using a controlled subsurface drainage/irrigation system, with a focus on nutrient uptake at black layer formation. In a subsequent manuscript we will describe nutrient concentrations from tile drain effluents and note their potential impact on surface water resources. Crop yields using the controlled subsurface drainage/irrigation system substantially increased grain yields in 2008, 2011 and 2012 relative to previous corn production prior to the installation of the controlled subsurface drainage/irrigation system. Nutrient uptake (N, P, K, Ca, Mg, S, Fe, Mn, B, Cu, and Zn) was partitioned into leaf blades (blades), leaf sheaths (sheaths), culm (stem), tassel, ear leaves, shank, cob and grain. Nutrient concentrations in plant parts were estimated using plant tissue analysis, plant populations and dry matter production and expressed on a field basis (kg ha^{-1}). The nutrient uptake by plant part at black layer showed that N, P, and S were more than 50% vested with grain. The remaining nutrients were primarily associated with the non-grain plant parts, especially K, Ca and B.*

Key Words: *Drainage, Irrigation, Nutrient Uptake, Corn*

Introduction

The purpose of this manuscript is to describe the nutrient uptake and yield performance of corn with a controlled subsurface drainage and irrigation system. Corn (maize) is a tall annual cereal plant that produces densely packed ears of grains attached to a central core (spike). Residues produced by corn have nutrient concentrations that when returned to the soil support sustainable agricultural practices, resist water erosion by raindrop intercepts, and limit nutrient leaching.

Materials and Methods

Corn Design

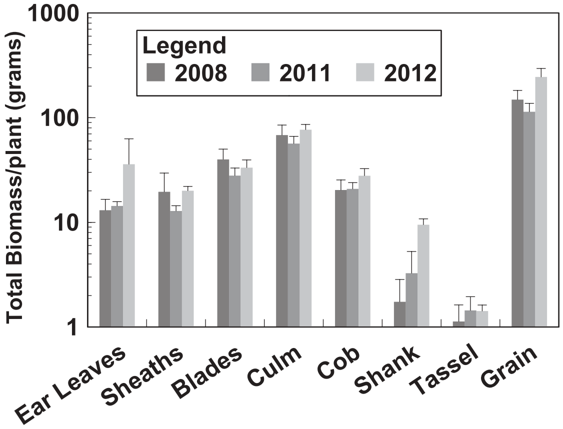
Corn plots planted in April of 2008, 2011 and 2012 on 0.77 meter (30 inch) row spacing. Plot dimensions were 12 rows wide and 30 meters in length. Row directions were perpendicular to the tile-line direction. Corn populations averaged 71,630 plants / ha. Corn varieties (A6533VT2 RIB in 2012 and A6553VT2 Pro/RR in 2011) having Round-up Ready® traits were planted, except for small parcels of land having traditional corn plants as a non-biotechnology refuge. All treatments were replicated five times.

Phosphorus [diammonium phosphate (16-48-0)] and K [potash (0-0-60)] fertilizer was pre-plant applied using variable-rate technology based on grid soil sampling, whereas the N rates were 134 kg/ha (120 lbs/acre) of N as liquid N (28% N-solution) one to three days pre-plant, with 179 kg/ha (160 lbs/acre) of N as liquid N applied five weeks post-planting, which was based on stand density and yield goal.

Tissue testing (N, P, K, Ca, Mg, S, Na, Al, Fe, Mn, Zn, B, and Cu) and plant biomass accumulation were conducted just prior to harvest. Corn sampling included total biomass and nutrient concentrations associated with culm (stem), axial sheaths, axial blades, cob, shank, ear leaves, tassel and seed, with total plant uptake and biomass accumulation estimated by the summation of the plant parts after the product of dry matter and nutrient concentrations. Biomass sampling involved randomly selecting four plants from each of the five replicates. Manual separation of the plant parts was followed by drying at 70ºC for two days and then weighing. Population estimates were performed by counting all plants in a 3.1 meter row, which was replicated five times for each replicate plot. All plant tissue analysis was performed by Mid-West Laboratories (Omaha, NE).

Two yield estimates were obtained from each of the five replicates to determine: (1) the average yield and (2) the yield difference between areas planted directly over the drainage/irrigation tiles and those planted between the drainage/irrigation tiles. Given that the drainage/irrigation tiles are on 10 m centers, the midpoint of one sample was taken directly

Figure 1. The percentage distribution of biomass components (error bars are the standard deviations).



over the tile, and the mid-point of one sample was equidistant between the tile-lines. The ears were harvested from plants within a randomly selected 3 meter row. The number of ears was counted from each plot and the grain husked and shelled, weighed and the weight adjusted to 15.5 percent moisture. The average yields were determined by extrapolating the weights to that of a hectare (ha). Field yield as also estimated from yield monitors in a combine.

Results

Corn Harvest Biomass and Nutrient Accumulation Patterns

Biomass Accumulation: The dry-matter biomass distribution among the plant components (ear leaves, axial sheaths, axial blades (sheaths and blades were combined in 2008), culm, cob, shank, tassel and grain) show that the greatest biomass accumulations in the grain, followed closely by the culm and leaf blades (Fig. 1). The 2012 growing season exhibited the greatest biomass accumulation, which correlated with the highest yields in 2012. The field yields in 2008, 2011 and 2012 were 167, 176 and 196 bushel / acre, respectively. These yields are comparable or superior to county averages, especially in the drought year of 2012.

Total Nutrient Uptake: The total partitioning of the nutrients at maturity in 2008, 2011 and 2012 indicate that the grain component is the largest reservoir for N, P, and S (Tables 1a, 1b, and 1c). In 2012, Zn was primarily associated with the grain component. Conversely, K, Mg, Ca, Fe, Mn, B abd Cu were predominantly associated with the culm and axial leaves. Yield differences were not significantly different for plots superimposed over the irrigation lines and plots equidistant between the irrigation lines.

The residues (collectively the non-grain biomass) are an important soil fertility consideration. Field removal of the residues because of silage or cellulosic ethanol production requires management of the soil resource to replace nutrients and to limit carbon loss. Potassium is an element having the most immediate concern, primarily because of the magnitude of the uptake. Calcium, P and S were also plant essential nutrients having appreciable residues concentrations and whose return to the soil environment is important for soil nutrient sustainability.

Summary

The soils of this study have sufficient reserves of plant essential elements to support plant growth and development. The major soil limitations include: (1) seasonal wetness and (2) low soil organic matter contents. Both conditions could limit available nitrogen because of insufficient mineralization and denitrification. Controlled drainage limits the effects of seasonal wetness; thereby, promoting soil aeration, optimum root respiration and root growth. The corn yields approached record levels for Cape Girardeau County, and the nutrient uptake was

Table 1a. Estimated total nutrient uptake (kg/ha) by corn at black layer formation in 2008.

Part	N	P	K	Mg	Ca	S	Fe	Mn	B	Cu	Zn
Stem	31	4.1	25.7	7.3	18.0	2.6	0.37	0.08	0.02	0.03	0.08
Leaves	115	18.9	71.8	11.9	57.0	10.3	0.55	0.92	0.06	0.08	0.25
Tassel	1	0.2	2.0	0.1	0.4	0.1	0.007	0.02	0.003	0.001	0.00
Shank	1	0.1	3.7	0.02	0.1	0.05	0.005	0.001	0.001	0.002	0.00
Cob	11	1.1	8.2	0.4	1.2	0.8	0.03	0.009	0.005	0.007	0.02
Ear leaf	6	1.1	11.2	0.8	1.9	0.4	0.03	0.05	0.004	0.003	0.02
Grain	**159**	**36.1**	**53.0**	**10.2**	**1.1**	**12.4**	**0.20**	**0.06**	**0.02**	**0.03**	**0.26**
Total	**325**	**62**	**177**	**27**	**81**	**27**	**1.1**	**1.1**	**0.11**	**0.2**	**0.6**

Table 1b. Estimated total nutrient uptake (kg/ha) by corn at black layer formation in 2011.

Part	N	P	K	Mg	Ca	S	Fe	Mn	B	Cu	Zn
Stem	32.8	2.4	30.4	8.6	15.2	1.9	0.10	0.18	0.02	0.02	0.10
Blades	49.9	4.5	26.0	4.9	26.7	4.9	0.49	1.07	0.02	0.05	0.04
Sheaths	8.9	0.8	10.1	5.2	9.0	0.9	0.12	0.43	0.01	0.01	0.02
Tassel	1.9	0.2	1.1	0.2	0.6	0.2	0.02	0.03	0.00	0.00	0.01
Shank	2.1	0.2	5.3	0.3	0.5	0.1	0.01	0.01	0.00	0.00	0.01
Cob	10.3	1.6	9.8	0.4	0.4	0.5	0.03	0.02	0.00	0.01	0.06
Ear leaf	6.9	0.6	11.1	1.6	2.5	0.5	0.04	0.09	0.01	0.01	0.02
Grain	**106.1**	**23.9**	**35.4**	**6.7**	**1.0**	**10.5**	**0.18**	**0.09**	**0.02**	**0.02**	**0.20**
Total	218	34	129	27.8	55.9	19.5	1.0	1.9	0.08	0.1	0.5

Table 1c. Estimated total nutrient uptake (kg/ha) by corn at black layer formation in 2012.

Part	N	P	K	Mg	Ca	S	Fe	Mn	B	Cu	Zn
Stem	96	6.5	125.3	9.5	20.8	3.6	0.26	0.21	0.01	0.03	0.09
Blades	47.3	4.9	60.0	2.6	30.8	7.5	0.29	1.22	0.09	0.05	0.09
Sheaths	17.8	1.5	32.8	2.8	12.2	1.4	0.14	0.27	0.02	0.01	0.02
Tassel	1.5	0.2	2.0	0.1	0.6	0.1	0.00	0.01	0.02	0.00	0.00
Shank	12.2	1.5	24.2	0.4	1.0	0.6	0.02	0.03	0.00	0.01	0.02
Cob	30.1	1.5	29.1	0.9	1.7	1.5	0.09	0.06	0.01	0.01	0.05
Ear leaf	25.5	2.8	45.9	2.8	8.3	1.4	0.14	0.32	0.02	0.01	0.06
Grain	**314.2**	**79.5**	**107.9**	**20.8**	**1.9`**	**22.7**	**0.42**	**0.21**	**0.04**	**0.06**	**0.59**
Total	544	99	427	40	77	39	1.4	2.4	0.2	0.2	0.9

commensurate. The quantity of N, P and other nutrients located in the biomass is an important component in the nutrient budget. Economic analysis of the agronomic performance of the subsurface controlled irrigation system shows that the yield increases and the existing corn market prices allow producer profitability (data not shown), with an eight year requirement to pay for the controlled subsurface drainage and irrigation installation.