

Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Corn

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Summary

Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize the production of irrigated corn in western Kansas. In 2020, N applied alone increased yields by 85 bu/a, whereas P applied alone increased yields by 10 bu/a. Nitrogen and P applied together increased yields up to 136 bu/a, which is 11 bu/a less than the 10-year average (2011–2020) of 147 bu/a. The application of 120 lb N/a (with highest P rate) produced 98% of maximum yield in 2020, which is greater than the 10-year average. The application of 80 instead of 40 lb P₂O₅/a increased average yields 1 bu/a. Average grain N content reached a maximum of 0.6 lb/bu while grain P content reached a maximum of 0.15 lb/bu (0.34 lb P₂O₅/bu). At the highest N and P rate, apparent fertilizer nitrogen recovery in the grain (AFNR_g) was 43%, and apparent fertilizer phosphorus recovery in the grain (AFPR_g) was 63%.

Introduction

This study was initiated in 1961 to determine responses of continuous corn and grain sorghum grown under flood irrigation to N, P, and potassium (K) fertilization. The study is conducted on a Ulysses silt loam soil with an inherently high K content. No yield benefit to corn from K fertilization was observed in 30 years, and soil K levels remained high, so the K treatment was discontinued in 1992 and replaced with a higher P rate.

Procedures

This field study is conducted at the Tribune Unit of the Kansas State University Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a without P and K; with 40 lb/a P₂O₅ and zero K; and with 40 lb/a P₂O₅ and 40 lb/a K₂O. The treatments were changed in 1992; the K variable was replaced by a higher rate of P (80 lb/a P₂O₅). All fertilizers were broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. The corn hybrids (Pioneer 1151XR, 2011; Pioneer 0832, 2012–2013; Pioneer 1186AM, 2014; Pioneer 35F48 AM1, 2015; Pioneer 1197, 2016; Pioneer 0801, 2017–2018; Pioneer 0339, 2019; and Mycogen 10Z29, 2020) were planted at about 32,000 seeds/a in late April or early May. Hail damaged the 2015, 2017, 2019, and 2020 crops. The corn is irrigated to minimize water stress. Sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 15.5% moisture. Grain samples were collected at harvest, dried, ground, and analyzed for N and P concentrations. Grain N and P content (lb/bu) and removal (lb/a) were calculated. Apparent fertilizer N recovery in the grain

(AFNR_g) was calculated as N uptake in treatments receiving N fertilizer minus N uptake in the unfertilized control divided by N rate. The same approach was used to calculate apparent fertilizer P recovery in the grain (AFPR_g).

Results

Corn yields in 2020 were similar to the 10-year average (Table 1). Nitrogen alone increased yields 85 bu/a, whereas P alone increased yields 10 bu/a. However, N and P applied together increased corn yields up to 136 bu/a. Maximum yield was obtained with 200 lb/a N with 80 lb/a P₂O₅. Corn yields in 2020 (averaged across all N rates) were 1 bu/a greater with 80 than with 40 lb/a P₂O₅.

The 10-year average grain N concentration (%) increased with N rates but tended to decrease when P was also applied, presumably because of higher grain yields diluting N content (Table 2). Grain N content reached a maximum of 0.6 lb/bu. Nitrogen removal (lb/a) was greater at the higher yield levels. Maximum N removal (121 lb/a), was attained with 200 lb N and 80 lb P₂O₅/a. At the highest N and P rate, AFNR_g was 43% and AFPR_g was 63%. Similar to N, the average P concentration increased with increased P rates but decreased with higher N rates. Grain P content (lb/bu) of about 0.15 lb P/bu (0.34 lb P₂O₅/bu) was greater at the highest P rate with low N rates. Grain P removal averaged 31 lb P/a at the highest yields.

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Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2011–2020

| Fertilizer | | Yield | | | | | | | | | | |
|----------------|-------------------------------|------------------|------|------|------|------|------|------|------|------|------|------|
| N | P ₂ O ₅ | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Mean |
| ---- lb/a ---- | | ----- bu/a ----- | | | | | | | | | | |
| 0 | 0 | 92 | 86 | 70 | 86 | 92 | 74 | 44 | 82 | 76 | 79 | 78 |
| 0 | 40 | 111 | 85 | 80 | 95 | 103 | 78 | 47 | 93 | 86 | 88 | 87 |
| 0 | 80 | 105 | 94 | 91 | 98 | 104 | 86 | 52 | 99 | 83 | 89 | 90 |
| 40 | 0 | 114 | 109 | 97 | 106 | 113 | 105 | 60 | 110 | 93 | 98 | 100 |
| 40 | 40 | 195 | 138 | 125 | 153 | 164 | 145 | 92 | 160 | 156 | 168 | 150 |
| 40 | 80 | 194 | 135 | 126 | 149 | 162 | 135 | 90 | 159 | 154 | 153 | 146 |
| 80 | 0 | 136 | 128 | 112 | 117 | 131 | 118 | 70 | 117 | 117 | 121 | 117 |
| 80 | 40 | 212 | 197 | 170 | 187 | 195 | 196 | 132 | 212 | 183 | 191 | 187 |
| 80 | 80 | 220 | 194 | 149 | 179 | 193 | 193 | 129 | 207 | 189 | 191 | 184 |
| 120 | 0 | 119 | 134 | 114 | 115 | 124 | 109 | 62 | 102 | 95 | 100 | 107 |
| 120 | 40 | 222 | 213 | 204 | 213 | 212 | 212 | 142 | 218 | 193 | 205 | 204 |
| 120 | 80 | 225 | 211 | 194 | 216 | 216 | 223 | 162 | 243 | 201 | 210 | 210 |
| 160 | 0 | 157 | 158 | 122 | 128 | 144 | 142 | 84 | 139 | 133 | 129 | 133 |
| 160 | 40 | 229 | 227 | 199 | 211 | 215 | 226 | 154 | 230 | 196 | 206 | 209 |
| 160 | 80 | 226 | 239 | 217 | 233 | 216 | 238 | 165 | 251 | 191 | 208 | 218 |
| 200 | 0 | 179 | 170 | 139 | 144 | 162 | 159 | 114 | 158 | 147 | 164 | 154 |
| 200 | 40 | 218 | 225 | 198 | 204 | 214 | 216 | 148 | 231 | 186 | 205 | 205 |
| 200 | 80 | 231 | 260 | 220 | 238 | 221 | 235 | 174 | 243 | 207 | 215 | 225 |

continued

Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2011–2020

| Fertilizer | | Yield | | | | | | | | | | |
|--------------------------------------|-------------------------------|------------------|-------|--------|--------|--------|-------|-------|-------|--------|--------|-------|
| N | P ₂ O ₅ | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Mean |
| ---- lb/a ---- | | ----- bu/a ----- | | | | | | | | | | |
| ANOVA (P>F) | | | | | | | | | | | | |
| Nitrogen | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Linear | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Quadratic | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Phosphorus | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Linear | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Quadratic | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| N × P | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| MEANS | | | | | | | | | | | | |
| Nitrogen, lb/a | | | | | | | | | | | | |
| 0 | | 103 d | 88 f | 80 e | 93 e | 100 e | 79 e | 48 e | 91 d | 82 d | 85 e | 85 e |
| 40 | | 167 c | 127 e | 116 d | 136 d | 146 d | 129 d | 81 d | 143 c | 135 c | 140 d | 132 d |
| 80 | | 189 b | 173 d | 143 c | 161 c | 173 c | 169 c | 110 c | 179 b | 163 b | 168 c | 163 c |
| 120 | | 189 b | 186 c | 171 b | 181 b | 184 b | 182 b | 122 b | 188 b | 163 b | 172 bc | 174 b |
| 160 | | 204 a | 208 b | 179 ab | 190 ab | 192 ab | 202 a | 134 a | 207 a | 173 ab | 181 b | 187 a |
| 200 | | 209 a | 218 a | 186 a | 196 a | 199 a | 203 a | 145 a | 211 a | 180 a | 195 a | 194 a |
| LSD _(0.05) | | 13 | 10 | 10 | 10 | 9 | 10 | 11 | 13 | 13 | 13 | 8 |
| P ₂ O ₅ , lb/a | | | | | | | | | | | | |
| 0 | | 133 b | 131 c | 109 b | 116 c | 128 b | 118 b | 72 c | 118 c | 110 b | 115 b | 115 b |
| 40 | | 198 a | 181 b | 163 a | 177 b | 184 a | 179 a | 119 b | 191 b | 167 a | 177 a | 173 a |
| 80 | | 200 a | 189 a | 166 a | 186 a | 185 a | 185 a | 129 a | 200 a | 171 a | 178 a | 179 a |
| LSD _(0.05) | | 9 | 7 | 7 | 7 | 6 | 7 | 8 | 9 | 9 | 9 | 6 |

Different letters in the same column indicate significant differences ($P < 0.05$).

Hail events occurred on 8/18/2017, 9/20/2019, and 8/10/2020.

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2011–2020

| Fertilizer | | Grain | | | | Grain removal | | | |
|------------------|-------------------------------|---------------|-------|-------------------|-------|------------------|----|--------------------|--------------------|
| N | P ₂ O ₅ | N | P | N | P | N | P | *AFNR _g | *AFPR _g |
| ----- lb/a ----- | | ----- % ----- | | ----- lb/bu ----- | | ----- lb/a ----- | | ----- % ----- | |
| 0 | 0 | 0.96 | 0.231 | 0.46 | 0.109 | 36 | 9 | --- | --- |
| 0 | 40 | 0.91 | 0.312 | 0.43 | 0.148 | 37 | 13 | --- | 24 |
| 0 | 80 | 0.91 | 0.324 | 0.43 | 0.153 | 39 | 14 | --- | 15 |
| 40 | 0 | 1.15 | 0.187 | 0.55 | 0.088 | 54 | 9 | 47 | --- |
| 40 | 40 | 0.93 | 0.300 | 0.44 | 0.142 | 66 | 21 | 77 | 71 |
| 40 | 80 | 0.94 | 0.319 | 0.44 | 0.151 | 65 | 22 | 74 | 38 |
| 80 | 0 | 1.25 | 0.182 | 0.59 | 0.086 | 68 | 10 | 41 | --- |
| 80 | 40 | 1.02 | 0.250 | 0.48 | 0.118 | 90 | 22 | 69 | 76 |
| 80 | 80 | 0.99 | 0.307 | 0.47 | 0.145 | 86 | 27 | 64 | 51 |
| 120 | 0 | 1.28 | 0.175 | 0.60 | 0.083 | 64 | 9 | 24 | --- |
| 120 | 40 | 1.10 | 0.228 | 0.52 | 0.108 | 106 | 22 | 59 | 75 |
| 120 | 80 | 1.06 | 0.293 | 0.50 | 0.139 | 106 | 29 | 59 | 58 |
| 160 | 0 | 1.25 | 0.180 | 0.59 | 0.085 | 78 | 11 | 27 | --- |
| 160 | 40 | 1.15 | 0.241 | 0.54 | 0.114 | 114 | 24 | 49 | 86 |
| 160 | 80 | 1.13 | 0.273 | 0.53 | 0.129 | 116 | 28 | 51 | 55 |
| 200 | 0 | 1.21 | 0.190 | 0.57 | 0.090 | 87 | 14 | 26 | --- |
| 200 | 40 | 1.14 | 0.232 | 0.54 | 0.110 | 110 | 23 | 38 | 79 |
| 200 | 80 | 1.14 | 0.290 | 0.54 | 0.137 | 121 | 31 | 43 | 63 |

continued

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2011–2020

| Fertilizer | | Grain | | | | Grain removal | | | |
|--------------------------------------|-------------------------------|---------------|----------|-------------------|----------|------------------|-------|--------------------|--------------------|
| N | P ₂ O ₅ | N | P | N | P | N | P | *AFNR _g | *AFPR _g |
| ----- lb/a ----- | | ----- % ----- | | ----- lb/bu ----- | | ----- lb/a ----- | | ----- % ----- | |
| ANOVA (P>F) | | | | | | | | | |
| Nitrogen | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Linear | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | --- | 0.001 |
| Quadratic | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | --- | 0.001 |
| Phosphorus | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Linear | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | --- |
| Quadratic | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | --- |
| N × P | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.047 | 0.056 |
| MEANS | | | | | | | | | |
| Nitrogen, lb/a | | | | | | | | | |
| 0 | | 0.93 d | 0.289 a | 0.44 d | 0.137 a | 37 e | 12 e | --- | 20 c |
| 40 | | 1.01 c | 0.269 b | 0.48 c | 0.127 b | 62 d | 17 d | 66 a | 55 b |
| 80 | | 1.09 b | 0.246 c | 0.51 b | 0.117 c | 82 c | 20 c | 58 b | 64 a |
| 120 | | 1.15 a | 0.232 d | 0.54 a | 0.110 d | 92 b | 20 bc | 47 c | 67 a |
| 160 | | 1.17 a | 0.231 d | 0.56 a | 0.109 d | 103 a | 21 ab | 42 c | 71 a |
| 200 | | 1.16 a | 0.237 cd | 0.55 a | 0.112 cd | 106 a | 22 a | 35 d | 71 a |
| LSD _(0.05) | | 0.03 | 0.011 | 0.01 | 0.005 | 4 | 1 | 5 | 9 |
| P ₂ O ₅ , lb/a | | | | | | | | | |
| 0 | | 1.18 a | 0.191 c | 0.56 a | 0.090 c | 65 b | 10 c | 33 b | --- |
| 40 | | 1.04 b | 0.260 b | 0.49 b | 0.123 b | 87 a | 21 b | 58 a | 69 a |
| 80 | | 1.03 b | 0.301 a | 0.49 b | 0.143 a | 89 a | 25 a | 58 a | 47 b |
| LSD _(0.05) | | 0.02 | 0.008 | 0.01 | 0.004 | 3 | 1 | 4 | 5 |

*AFNR_g and AFPR_g = Apparent Fertilizer N Recovery (grain) and Apparent Fertilizer P Recovery (grain).
Different letters in the same column indicate significant differences ($P < 0.05$).