

## 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 production of irrigated corn in western Kansas. In 2017, N applied alone increased yields by 70 bu/a, whereas P applied alone increased yields by less than 10 bu/a. Nitrogen and P applied together increased yields up to 130 bu/a. This is 10 bu/a less than the 10-year average, where N and P fertilization increased corn yields up to 140 bu/a. Application of 120 lb/a N (with highest P rate) produced 93% of maximum yield in 2017, which is similar to the 10-year average. Application of 80 instead of 40 lb  $P_2O_5$ /a increased average yields 10 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  $P_2O_5$ /bu). At the highest N and P rate, apparent fertilizer nitrogen recovery in the grain (AFNR<sub>g</sub>) was 42% and apparent fertilizer phosphorus recovery in the grain (AFPR<sub>g</sub>) was 61%.

### 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  $P_2O_5$  and zero K; and with 40 lb/a  $P_2O_5$  and 40 lb/a  $K_2O$ . The treatments were changed in 1992; the K variable was replaced by a higher rate of P (80 lb/a  $P_2O_5$ ). All fertilizers were broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. The corn hybrids [Pioneer 34B99 (2008), DeKalb 61-69 (2009), Pioneer 1173H (2010), Pioneer 1151XR (2011), Pioneer 0832 (2012-2013), Pioneer 1186AM (2014), Pioneer 35F48 AM1 (2015), Pioneer 1197 (2016), and Pioneer 0801 (2017)] were planted at about 32,000 seeds/a in late April or early May. Hail damaged the 2008, 2010, and 2017 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 ( $AFPR_g$ ). Aerial application for grasshoppers was applied on July 18 and hail damage occurred on August 18.

## Results

Corn yields in 2017 were 25% lower than the 10-year average (Table 1). Nitrogen alone increased yields 70 bu/a, whereas P alone increased yields less than 10 bu/a. However, N and P applied together increased corn yields up to 130 bu/a. Maximum yield was obtained with 200 lb/a N with 80 lb/a  $P_2O_5$ . Corn yields in 2017 (averaged across all N rates) were 10 bu/a greater with 80 than with 40 lb/a  $P_2O_5$ .

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. Maximum N removal (lb/a) was greatest at the highest yield levels, which were attained with 200 lb N and 80 lb  $P_2O_5$ /a. At the highest N and P rate,  $AFNR_g$  was 42% and  $AFPR_g$  was 61%. Similar to N, 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  $P_2O_5$ /bu) was greater at the highest P rate with low N rates. Grain P removal averaged 29 lb P/a at the highest yields.

## Acknowledgment

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**Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2008-2017**

| Fertilizer       |                               | Yield            |      |      |      |      |      |      |      |      |      |      |
|------------------|-------------------------------|------------------|------|------|------|------|------|------|------|------|------|------|
| N                | P <sub>2</sub> O <sub>5</sub> | 2008             | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Mean |
| ----- lb/a ----- |                               | ----- bu/a ----- |      |      |      |      |      |      |      |      |      |      |
| 0                | 0                             | 36               | 85   | 20   | 92   | 86   | 70   | 86   | 92   | 74   | 44   | 68   |
| 0                | 40                            | 57               | 110  | 21   | 111  | 85   | 80   | 95   | 103  | 78   | 47   | 79   |
| 0                | 80                            | 52               | 106  | 28   | 105  | 94   | 91   | 98   | 104  | 86   | 52   | 82   |
| 40               | 0                             | 62               | 108  | 23   | 114  | 109  | 97   | 106  | 113  | 105  | 60   | 90   |
| 40               | 40                            | 105              | 148  | 67   | 195  | 138  | 125  | 153  | 164  | 145  | 92   | 133  |
| 40               | 80                            | 104              | 159  | 61   | 194  | 135  | 126  | 149  | 162  | 135  | 90   | 132  |
| 80               | 0                             | 78               | 123  | 34   | 136  | 128  | 112  | 117  | 131  | 118  | 70   | 105  |
| 80               | 40                            | 129              | 179  | 85   | 212  | 197  | 170  | 187  | 195  | 196  | 132  | 168  |
| 80               | 80                            | 139              | 181  | 90   | 220  | 194  | 149  | 179  | 193  | 193  | 129  | 167  |
| 120              | 0                             | 65               | 117  | 28   | 119  | 134  | 114  | 115  | 124  | 109  | 62   | 99   |
| 120              | 40                            | 136              | 202  | 90   | 222  | 213  | 204  | 213  | 212  | 212  | 142  | 185  |
| 120              | 80                            | 151              | 215  | 105  | 225  | 211  | 194  | 216  | 216  | 223  | 162  | 192  |
| 160              | 0                             | 84               | 139  | 49   | 157  | 158  | 122  | 128  | 144  | 142  | 84   | 121  |
| 160              | 40                            | 150              | 210  | 95   | 229  | 227  | 199  | 211  | 215  | 226  | 154  | 192  |
| 160              | 80                            | 146              | 223  | 95   | 226  | 239  | 217  | 233  | 216  | 238  | 165  | 200  |
| 200              | 0                             | 99               | 155  | 65   | 179  | 170  | 139  | 144  | 162  | 159  | 114  | 139  |
| 200              | 40                            | 152              | 207  | 97   | 218  | 225  | 198  | 204  | 214  | 216  | 148  | 188  |
| 200              | 80                            | 157              | 236  | 104  | 231  | 260  | 220  | 238  | 221  | 235  | 174  | 208  |

*continued*

**Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2008-2017**

| Fertilizer                           |                               | Yield            |       |       |       |       |       |       |       |       |       |       |
|--------------------------------------|-------------------------------|------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| N                                    | P <sub>2</sub> O <sub>5</sub> | 2008             | 2009  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 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                                    |                               | 48e              | 100e  | 23e   | 103d  | 88f   | 80e   | 93e   | 100e  | 79e   | 48e   | 76e   |
| 40                                   |                               | 91d              | 138d  | 50d   | 167c  | 127e  | 116d  | 136d  | 146d  | 129d  | 81d   | 118d  |
| 80                                   |                               | 115c             | 161c  | 70c   | 189b  | 173d  | 143c  | 161c  | 173c  | 169c  | 110c  | 146c  |
| 120                                  |                               | 118c             | 178b  | 74bc  | 189b  | 186c  | 171b  | 181b  | 184b  | 182b  | 122b  | 158b  |
| 160                                  |                               | 127b             | 191a  | 80ab  | 204a  | 208b  | 179ab | 190ab | 192ab | 202a  | 134a  | 171a  |
| 200                                  |                               | 136a             | 199a  | 89a   | 209a  | 218a  | 186a  | 196a  | 199a  | 203a  | 145a  | 178a  |
| LSD <sub>(0.05)</sub>                |                               | 9                | 12    | 9     | 13    | 10    | 10    | 10    | 9     | 10    | 11    | 7     |
| P <sub>2</sub> O <sub>5</sub> , lb/a |                               |                  |       |       |       |       |       |       |       |       |       |       |
| 0                                    |                               | 71b              | 121c  | 36b   | 133b  | 131c  | 109b  | 116c  | 128b  | 118b  | 72c   | 103c  |
| 40                                   |                               | 122a             | 176b  | 76a   | 198a  | 181b  | 163a  | 177b  | 184a  | 179a  | 119b  | 157b  |
| 80                                   |                               | 125a             | 187a  | 81a   | 200a  | 189a  | 166a  | 186a  | 185a  | 185a  | 129a  | 163a  |
| LSD <sub>(0.05)</sub>                |                               | 6                | 9     | 7     | 9     | 7     | 7     | 7     | 6     | 7     | 8     | 5     |

\*Note: Hail events on 7/23/10, 5/28/15, and 8/18/17.

**Table 2. Nitrogen and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2008-2017**

| Fertilizer       |                               | Grain         |       |                   |       | Grain removal    |    |                    |                    |
|------------------|-------------------------------|---------------|-------|-------------------|-------|------------------|----|--------------------|--------------------|
| N                | P <sub>2</sub> O <sub>5</sub> | N             | P     | N                 | P     | N                | P  | *AFNR <sub>g</sub> | *AFPR <sub>g</sub> |
| ----- lb/a ----- |                               | ----- % ----- |       | ----- lb/bu ----- |       | ----- lb/a ----- |    | ----- % -----      |                    |
| 0                | 0                             | 0.98          | 0.232 | 0.47              | 0.110 | 31               | 7  | ---                | ---                |
| 0                | 40                            | 0.95          | 0.313 | 0.45              | 0.148 | 34               | 12 | ---                | 25                 |
| 0                | 80                            | 0.95          | 0.322 | 0.45              | 0.152 | 36               | 12 | ---                | 15                 |
| 40               | 0                             | 1.17          | 0.184 | 0.55              | 0.087 | 49               | 8  | 45                 | ---                |
| 40               | 40                            | 0.97          | 0.304 | 0.46              | 0.144 | 60               | 19 | 73                 | 67                 |
| 40               | 80                            | 0.98          | 0.324 | 0.46              | 0.153 | 60               | 20 | 73                 | 36                 |
| 80               | 0                             | 1.26          | 0.181 | 0.60              | 0.085 | 62               | 9  | 38                 | ---                |
| 80               | 40                            | 1.05          | 0.259 | 0.50              | 0.122 | 83               | 20 | 65                 | 73                 |
| 80               | 80                            | 1.02          | 0.312 | 0.48              | 0.148 | 79               | 25 | 61                 | 49                 |
| 120              | 0                             | 1.26          | 0.175 | 0.60              | 0.083 | 58               | 8  | 23                 | ---                |
| 120              | 40                            | 1.13          | 0.230 | 0.54              | 0.109 | 98               | 20 | 56                 | 70                 |
| 120              | 80                            | 1.10          | 0.299 | 0.52              | 0.141 | 99               | 27 | 57                 | 55                 |
| 160              | 0                             | 1.25          | 0.179 | 0.59              | 0.085 | 71               | 10 | 25                 | ---                |
| 160              | 40                            | 1.18          | 0.245 | 0.56              | 0.116 | 106              | 22 | 47                 | 82                 |
| 160              | 80                            | 1.17          | 0.283 | 0.55              | 0.134 | 110              | 27 | 49                 | 54                 |
| 200              | 0                             | 1.24          | 0.188 | 0.59              | 0.089 | 80               | 12 | 25                 | ---                |
| 200              | 40                            | 1.19          | 0.241 | 0.56              | 0.114 | 105              | 21 | 37                 | 78                 |
| 200              | 80                            | 1.18          | 0.297 | 0.56              | 0.140 | 115              | 29 | 42                 | 61                 |

*continued*

**Table 2. Nitrogen and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2008-2017**

| Fertilizer                           |                               | Grain         |         |                   |         | Grain removal    |       |                    |                    |
|--------------------------------------|-------------------------------|---------------|---------|-------------------|---------|------------------|-------|--------------------|--------------------|
| N                                    | P <sub>2</sub> O <sub>5</sub> | N             | P       | N                 | P       | N                | P     | *AFNR <sub>g</sub> | *AFPR <sub>g</sub> |
| ----- 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 | 0.035              | 0.088              |
| Means                                |                               |               |         |                   |         |                  |       |                    |                    |
| Nitrogen, lb/a                       |                               |               |         |                   |         |                  |       |                    |                    |
| 0                                    |                               | 0.96e         | 0.289a  | 0.46e             | 0.137a  | 34f              | 10e   | ---                | 20d                |
| 40                                   |                               | 1.04d         | 0.271b  | 0.49d             | 0.128b  | 56e              | 16d   | 64a                | 52c                |
| 80                                   |                               | 1.11c         | 0.250c  | 0.53c             | 0.118c  | 75d              | 18c   | 55b                | 61b                |
| 120                                  |                               | 1.16b         | 0.235d  | 0.55b             | 0.111d  | 85c              | 18bc  | 45c                | 63ab               |
| 160                                  |                               | 1.20a         | 0.236d  | 0.57a             | 0.111d  | 96b              | 19b   | 40d                | 68ab               |
| 200                                  |                               | 1.20a         | 0.242cd | 0.57a             | 0.115cd | 100a             | 21a   | 35e                | 70a                |
| LSD <sub>(0.05)</sub>                |                               | 0.02          | 0.011   | 0.01              | 0.005   | 4                | 1     | 5                  | 8                  |
| P <sub>2</sub> O <sub>5</sub> , lb/a |                               |               |         |                   |         |                  |       |                    |                    |
| 0                                    |                               | 1.19a         | 0.190c  | 0.56a             | 0.090c  | 59b              | 9c    | 31b                | ---                |
| 40                                   |                               | 1.08b         | 0.265b  | 0.51b             | 0.126b  | 81a              | 19b   | 56a                | 66a                |
| 80                                   |                               | 1.07b         | 0.306a  | 0.50b             | 0.145a  | 83a              | 23a   | 56a                | 45b                |
| LSD <sub>(0.05)</sub>                |                               | 0.01          | 0.008   | 0.01              | 0.004   | 3                | 1     | 4                  | 5                  |

\*AFNR<sub>g</sub> and AFPR<sub>g</sub> = Apparent fertilizer N recovery (grain) and Apparent fertilizer P recovery (grain).