# Long-Term Fertilization Effects on Crop Yield and Nitrate-N Accumulation in Soil in Northwestern China

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## Background

Management practices have direct, indirect, immediate and long-term effects on crop yield and soil properties. Among these agronomic measures, fertilization may be the most important way to maintain high crop production. Combination of inorganic fertilizers and organic manure generally gives the best yields. The use of fertilizers has increased dramatically and this can result in more serious environmental consequences, such as nitrate contamination of drinking underground water and eutrophication. The long-term approach to minimize movement of nitrate into groundwater is to develop site-specific improved N fertilization and irrigation management practices to increase N uptake efficiency and to minimize leaching losses below the root zone. The objective of this study was determine the effects of chemical fertilizers and manure on grain and straw yield, total N concentration in grain and straw and accumulation of nitrate-N in the soil profile.

## Materials and Methods

The field experiment was conducted from 1982 to 2000 on a calcareous desert soil (sandy loam) near Zhangye city (38. 6°N, 100. 3°E; 1560 m altitude) in Hexi Corridor of Gansu Province in northwestern China. Twenty-four plots in a split-plot factorial were a combination of eight treatments [from nitrogen (N), phosphorus (P) and potassium (K) fertilizers and farmyard manure (M) applications] and three replications. The sources were N as ammonium nitrate or urea, P as single superphosphate or diammonium phosphate, K as potassium chloride and manure from a swine farm. Main plot treatments were M and no manure, and the sub-plot treatments were no-fertilizer control (CK), N, NP and NPK. So, the eight treatments were CK, N, NP, NPK, M, MN, MNP and MNPK.

The annual rate was 120-150 kg N $ha^{-1}$ for wheat and 240-450 kg N $ha^{-1}$ for corn; and it was 60-75 t M $ha^{-1}$ to each crop. When P and K were part of the treatment, their ratio to N was 1N: 0.22P: 0.42K. Half of the N was applied at planting and the other half was broadcast at 3-leaf stage for wheat; and N application was split as 30%, 30% and 40% at sowing, jointing and 10-leaf stages for corn, respectively. All M, P and K fertilizers were applied as a basal dressing. Irrigations (53-67 mm water per irrigation) were 3-4 times for wheat and 6-7 times for corn during each growing season. The crops were harvested for grain yield in all years. Representative grain samples were analyzed for total N. After the crop harvest of 2000, the soil in each plot was sampled from the 0-20, 20-60, 60-100, 100-140 and 140-180 cm depths to determine $NO_3$-N.

## Results

*Table 1, Figures 1, 2, 3 and 4*

Means of the 19-year grain yields were in the order of MNPK > MNP > NPK > MN > NP > M > N > CK. Corn grain yield of CK in 2000 was only 28.2% of that in 1984, and wheat grain yield in 1999 was 33.7% of that in 1982. The average impact of fertilizers on grain yield was in the order of N > M > P > K. Yield response to applied N and P increased with progression of the experiment, because the yields in the CK declined with time. The K fertilizer showed no increase in grain yield during the initial 6 years (1982-1987), moderate increase in the next 5 years 1988-1992, significant only in 1989), and dramatic increase in most cases in the last 8 years (1993-2000).

*Figure 5*

Chemical fertilizer and manure applications increased total N concentration in grain in all cases.

*Figures 6 and 7*

Accumulation and distribution of $NO_3$-N in the soil profile was significantly affected by the 19 annual applications of various fertilizers. Chemical fertilizers (N, NP and NPK) led to $NO_3$-N accumulation in most subsoil layers, with major impact in the 20-140 cm depth. Combined applications of chemical fertilizers and organic manure (MNP and MNPK) reduced soil $NO_3$-N accumulation compared to inorganic fertilizers alone. Substantial downward movement of $NO_3$-N from surface soil into subsoil below the root zone was considered a potential threat to groundwater pollution.

In summary, long-term fertilization significantly improved grain yield, straw yield and grain quality in this rotation. The findings suggest that it is very important to control chemical fertilizers rate as well as manure amount in order to protect soil and underground water from $NO_3$-N pollution.

## Conclusions

During 19 years, grain yields in the no-fertilization treatment (CK) declined and yield response to applied fertilizer treatments increased with time.

The impact of fertilizers on grain yields was N > M > P > K. Grain yield response of crops to applied N and P increased with time.

The K fertilizer showed no grain yield-increasing effect in the initial 6 years and its effect on grain yield increased with duration of the experiment.

Based on the 19-year data, the grain yields decreased in the order of MNPK > MNP > NPK > MN > NP > M > N > CK.

Chemical fertilizers and manure significantly increased concentration of total N of grain in all years.

From the point of increasing yields as well as maintaining soil productivity, the treatment of MNPK was the best fertilization strategy.

Annual fertilization for 19 years had a marked effect on $NO_3$-N accumulation in the soil profile.

Accumulation of $NO_3$-N in the 20-140 cm depth soil profile with application of chemical fertilizers (NP and NPK) suggests a potential danger of pollution to soil environment as well as the groundwater.

Compared to the chemical fertilizers alone, combined use of chemical fertilizers with manure (MN, MNP and MNPK) reduced residual soil $NO_3$-N to some extent.

The results also suggest that it is necessary to use appropriate chemical fertilizers as well as manure amounts to protect soil and underground water from potential $NO_3$-N pollution.

Table 1. Regressions of cumulative grain yield of crops with years in wheat-wheat-corn rotation from1982-2000 (kg ha$^{-1}$), treated annually with various combinations of N, P, K fertilizers and farmyard manure (M) on a calcareous sandy loam soil under irrigation near Zhangye Oasis, Gansu, China

| Year | Regression equation | $R^2$ |
|---|---|---|
| CK | y = 3358.6x + 11592 | 0.9336 |
| N | y = 4840.5x + 9436.1 | 0.9786 |
| NP | y = 7036.6x + 5082.0 | 0.9969 |
| NPK | y = 7606.1x + 2406.2 | 0.9975 |
| M | y = 5324.2x + 6067.8 | 0.9884 |
| MN | y = 7299.4x + 3145.6 | 0.9972 |
| MNP | y = 8046.2x + 2761.8 | 0.9973 |
| MNPK | y = 8095.2x + 1074.2 | 0.9968 |
| Mean-uM | y = 5710.7x + 7128.9 | 0.9921 |
| Mean-M | y = 7191.6x + 3261.9 | 0.9969 |

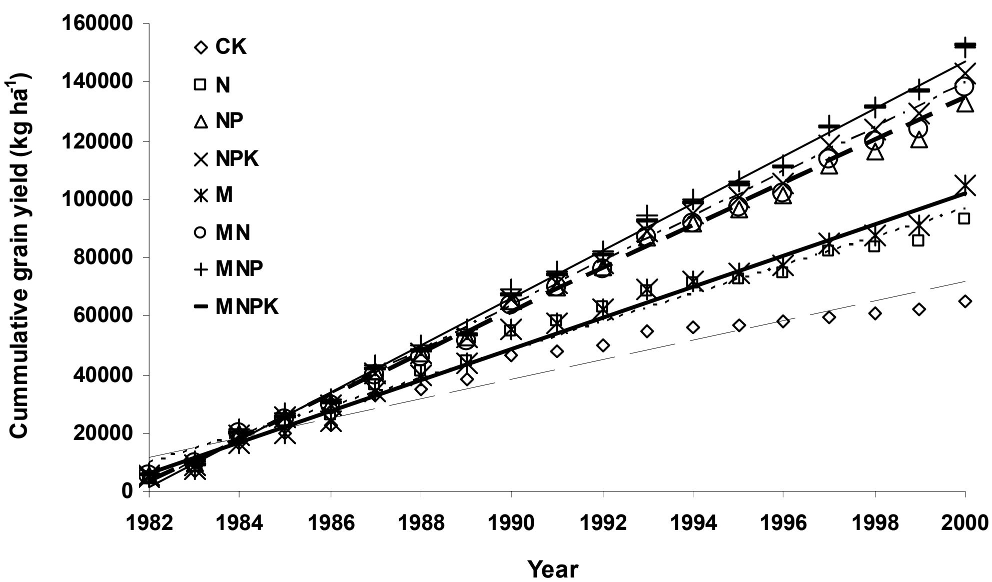


Figure 1. Regressions of cumulative grain yield of crops with years in wheat-wheat-corn rotation from 1982-2000 (kg ha$^{-1}$), treated annually with various combinations of N, P, K

fertilizers and unfertilized control (CK) without and with manure (M) on a calcareous sandy loam soil under irrigation near Zhangye, Gansu, China.

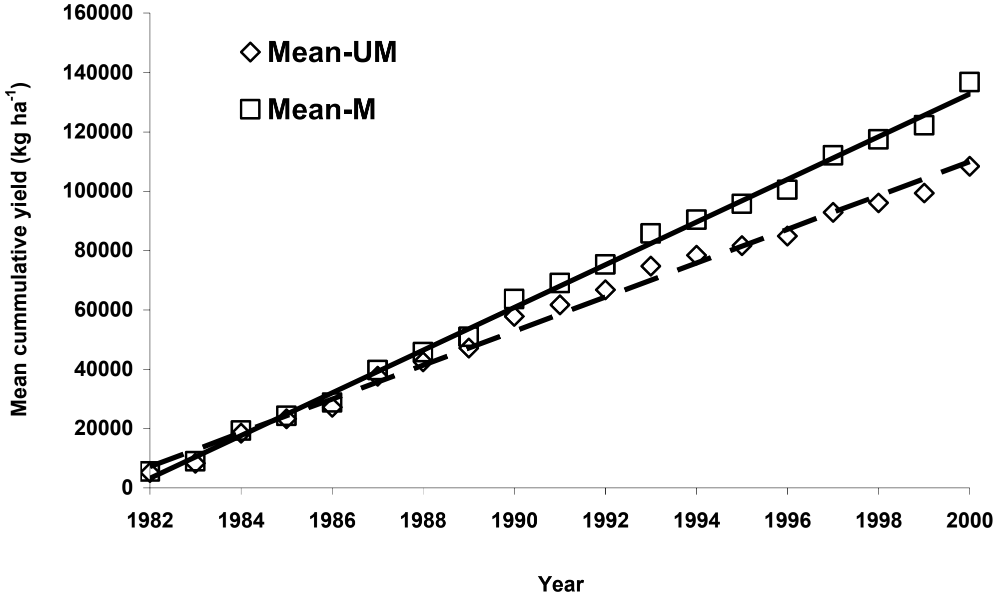


Figure 2. Regressions of cumulative grain yield (means) of crops with years in wheat-wheat-corn rotation from 1982-2000 (kg $ha^{-1}$), treated annually with various combinations of N, P, K fertilizers and unfertilized control (CK) without manure (UM) and with manure (M) on a calcareous sandy loam soil under irrigation near Zhangye, Gansu, China.

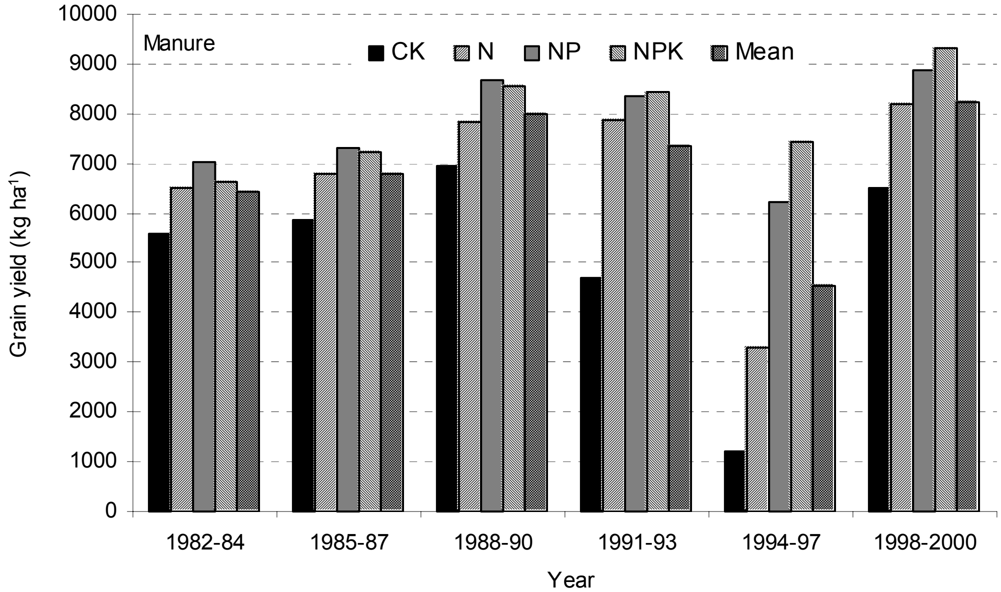


Figure 3. Grain yield (kg ha-1) for each rotation of wheat (W) and corn (C) crops from 1982-2000, treated annually with various combinations of N, P, K fertilizers and unfertilized control (CK) with manure (M) applied on a calcareous sandy loam soil under irrigation near Zhangye, Gansu, China.

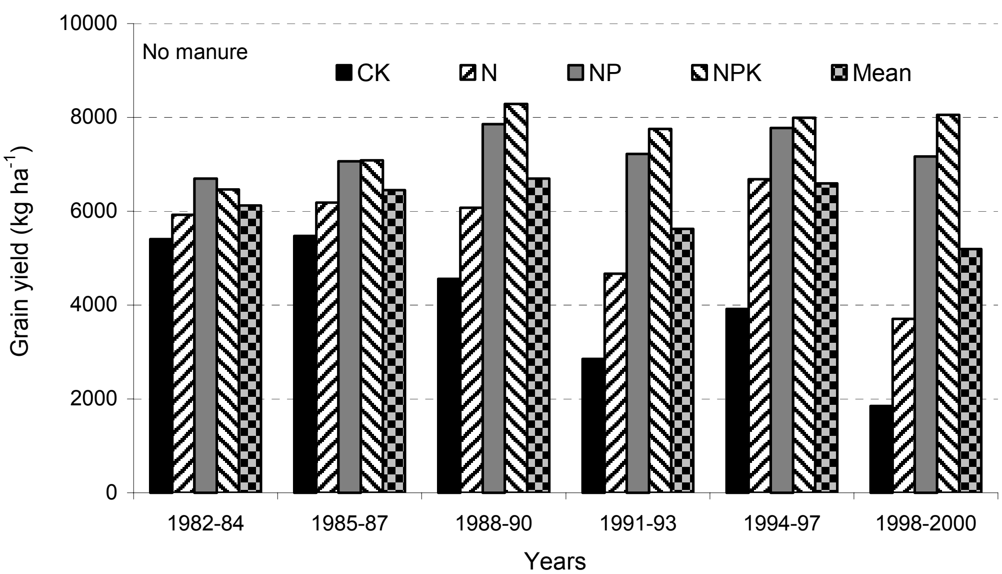


Figure 4. Grain yield (kg $ha^{-1}$) for each rotation of wheat (W) and corn (C) crops from 1982-2000, treated annually with various combinations of N, P, K fertilizers and unfertilized control (CK) without manure applied on a calcareous sandy loam soil under irrigation near Zhangye, Gansu, China.

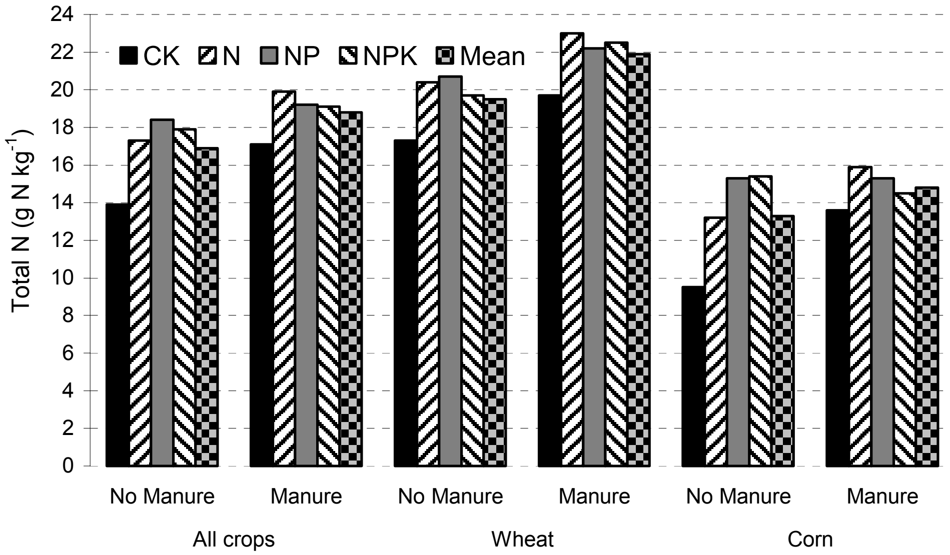


Figure 5. Concentration of total N (g N $kg^{-1}$) in grain of crops from 1987-2000, treated annually with various combinations of N, P, K fertilizers and unfertilized control (CK) without and with manure on a calcareous sandy loam soil under irrigation near Zhangye, Gansu, China.

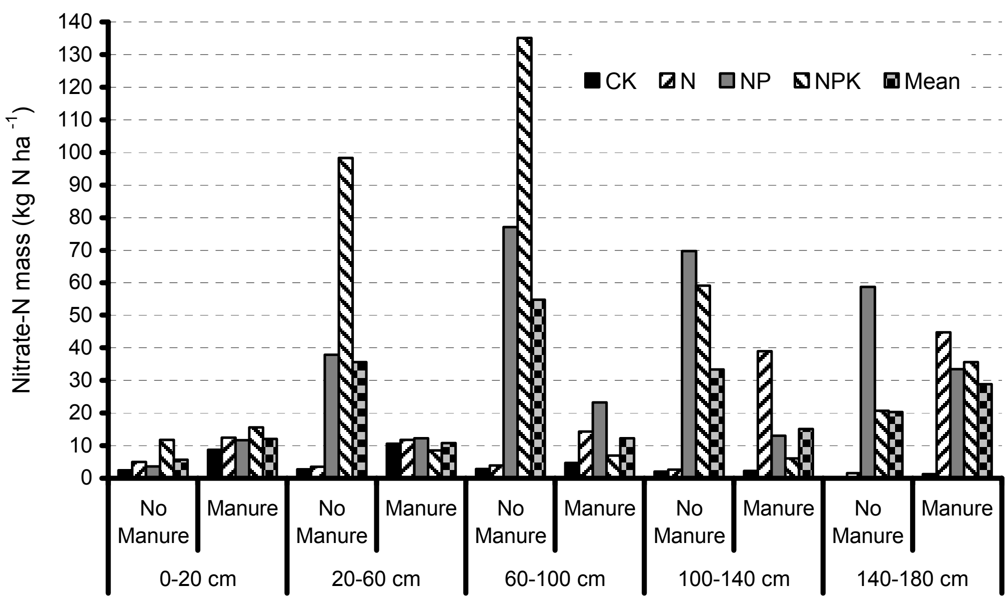


Figure 6. Nitrate-N mass (kg N $ha^{-1}$) in different soil layers after 19 annual applications of various combinations of N, P, K fertilizers and unfertilized control (CK) without and with manure on a calcareous sandy loam soil under irrigation near Zhangye, Gansu, China.

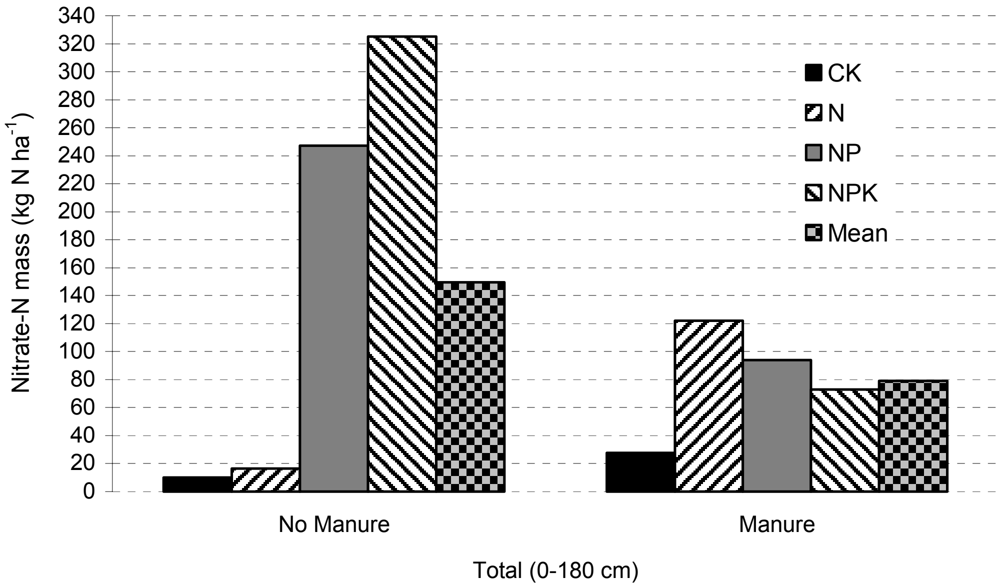


Figure 7. Nitrate-N mass (kg N $ha^{-1}$) in 0 to 180 cm after 19 annual applications of various combinations of N, P, K fertilizers and unfertilized control (CK) without and with manure on a calcareous sandy loam soil under irrigation near Zhangye, Gansu, China.