Probability of crop response to P and K fertilizer in Ohio

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Objectives

(1) Evaluate corn, soybean, and wheat grain yield responses to P and K fertilization

(2) Determine critical P and K soil test levels for corn, soybean, and wheat

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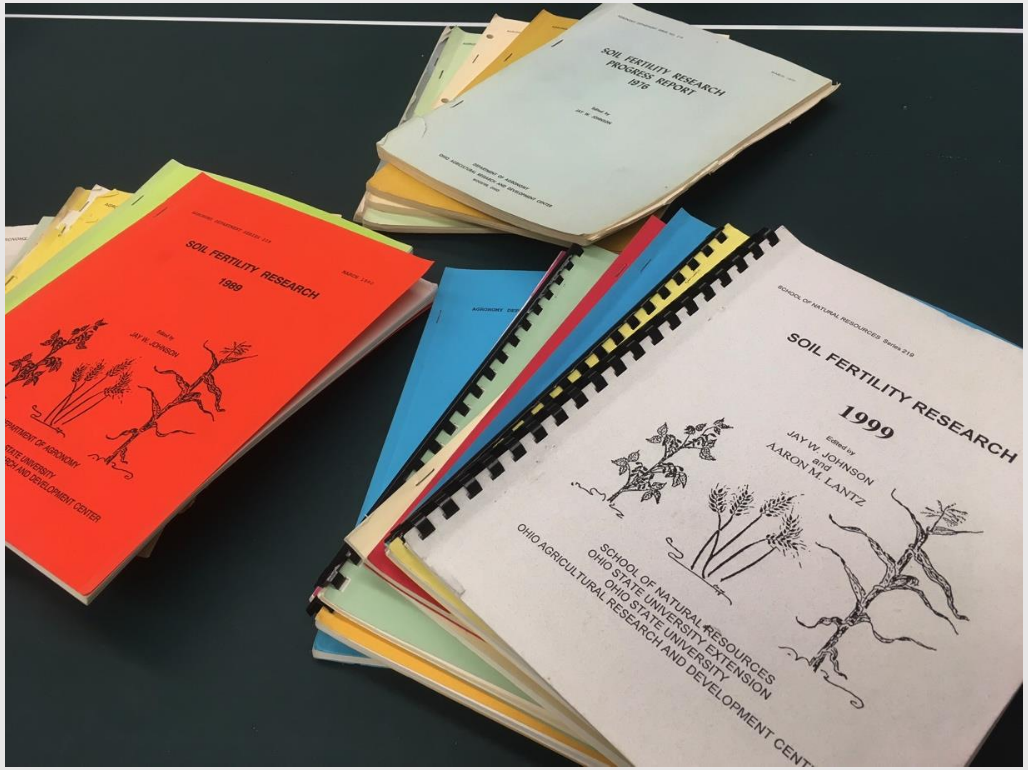
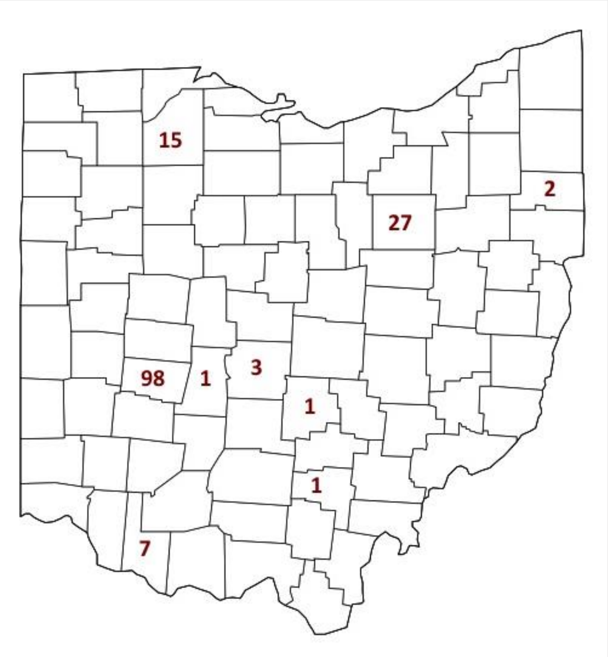
D1. Dataset #1

Annual Soil Fertility Reports: (1976 – 1999)

- 87 P trials, 110 K trials conducted
- 10 counties
- Small plot, many multi-year & multi-rate
- Corn, soybean, wheat

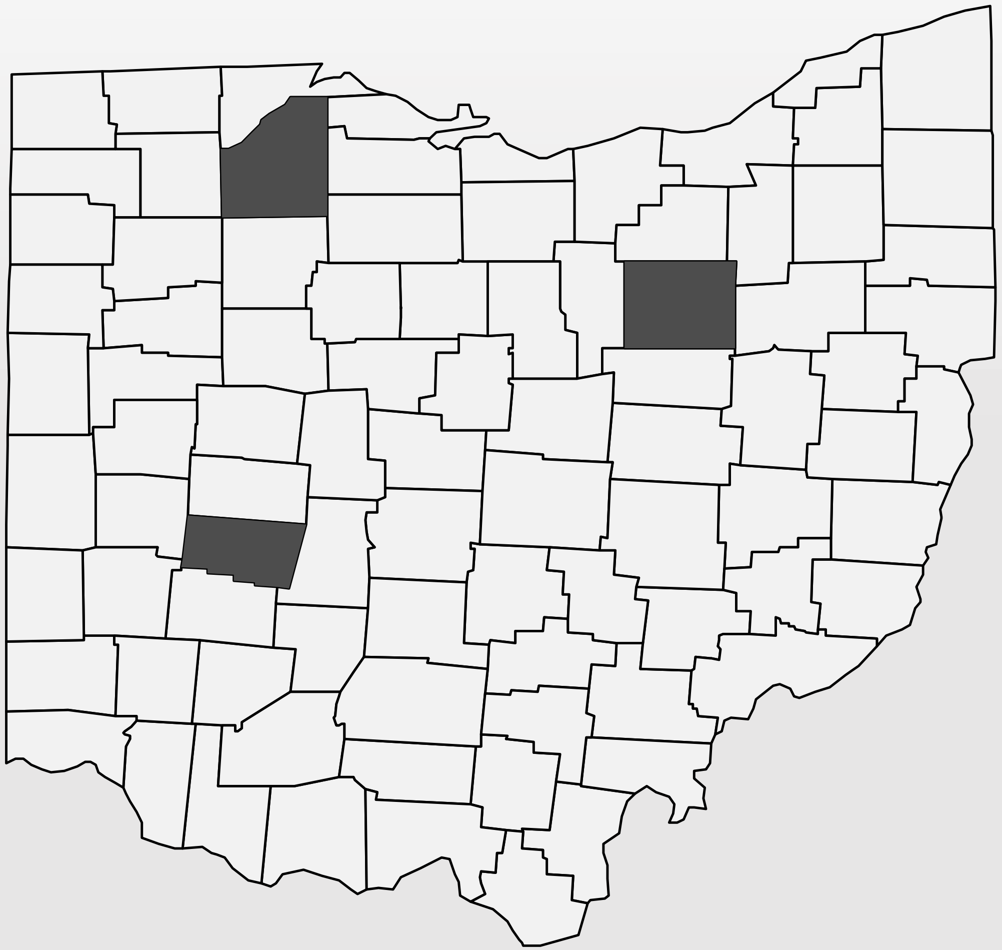




D2. Dataset #2

Long-term P & K Plots (2006-2021)

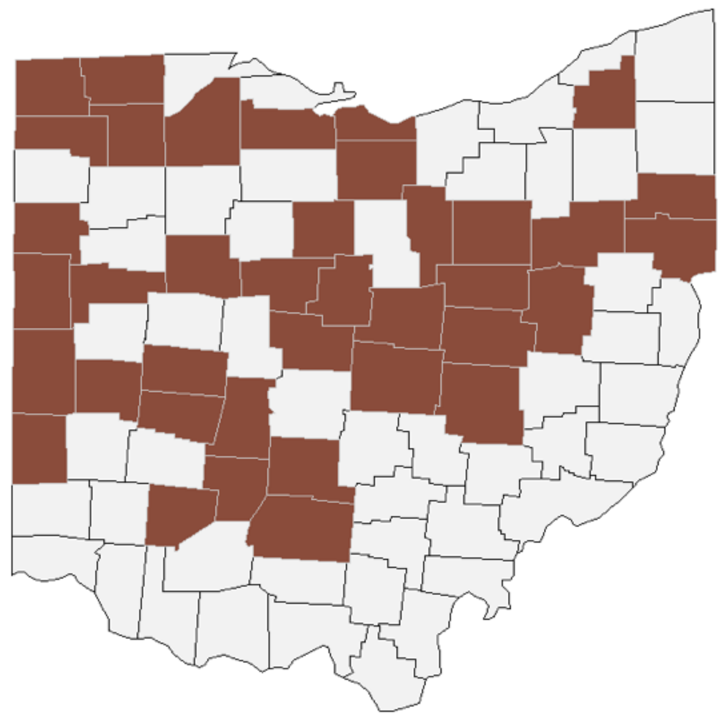
- 3 counties
- 252 P, 252 K Trials
  - P & K Fertilization
    - 3 rates (0, 1x, 2-3x)
  - Corn and soybean
- Small plot, university farms
- Multi-year & multi-rate



D3. Dataset #3

On-farm omission strip trials (2014-2018)

- 37 counties
- 118 P trials, 96 K trials
- Single rate of P or K
- Large and small plots, private farms
- Corn, soybean, wheat



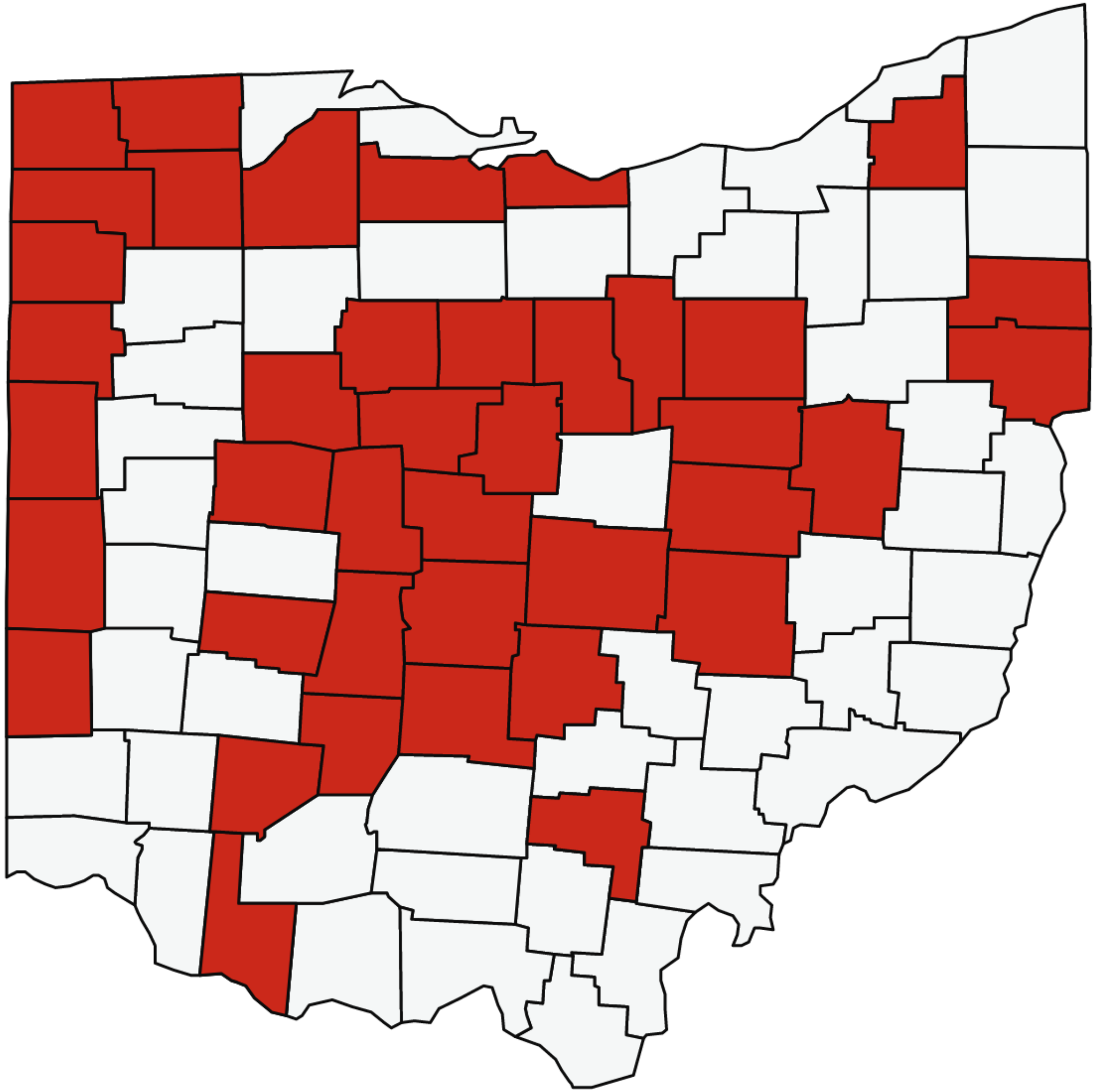
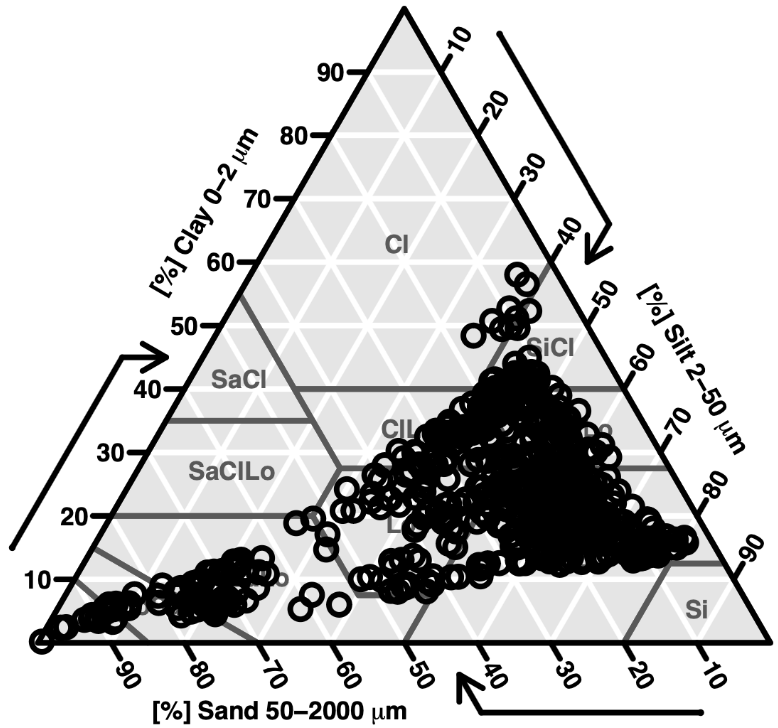


FIGURE 1 Ohio map with red, shaded counties ($n = 40$) denoting where P ($n = 457$) and K trials ($n = 459$) were conducted from 1976 to 2021.



Distribution of Soil Test Variables Across Datasets

Median M3P = 21.7 mg kg^{-1}

Median M3K = 98 mg kg^{-1}

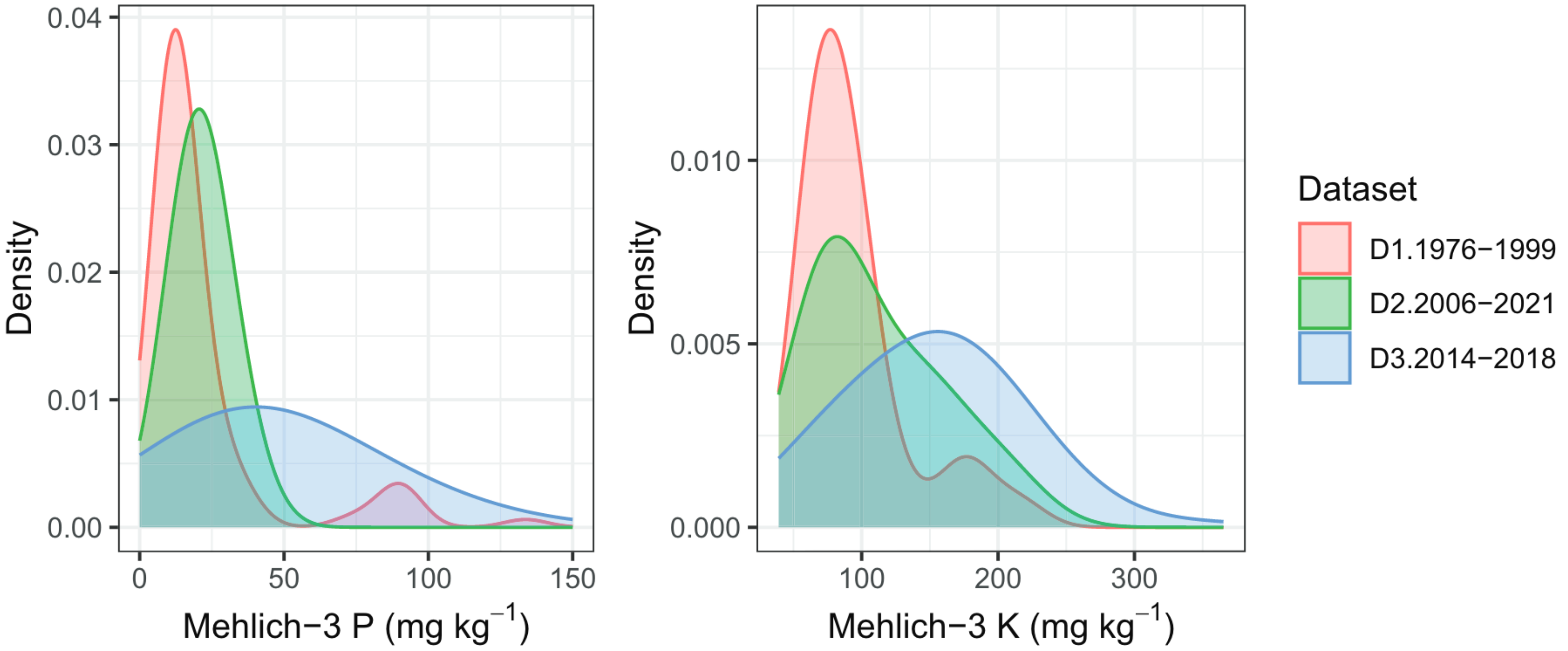


FIGURE 2 Distributions of Mehlich-3 P values in P trials (left panel) and Mehlich-3 K values in K trials by dataset. Datasets included D1 (small-plot, multi-rate trials), D2 (long-term trial at 3 sites), and D3 (on-farm omission trials). Mehlich-3 P values are only shown to 150 mg kg^{-1} for illustrative clarity.

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(1) Evaluate corn, soybean, and wheat grain yield responses to P and K fertilization

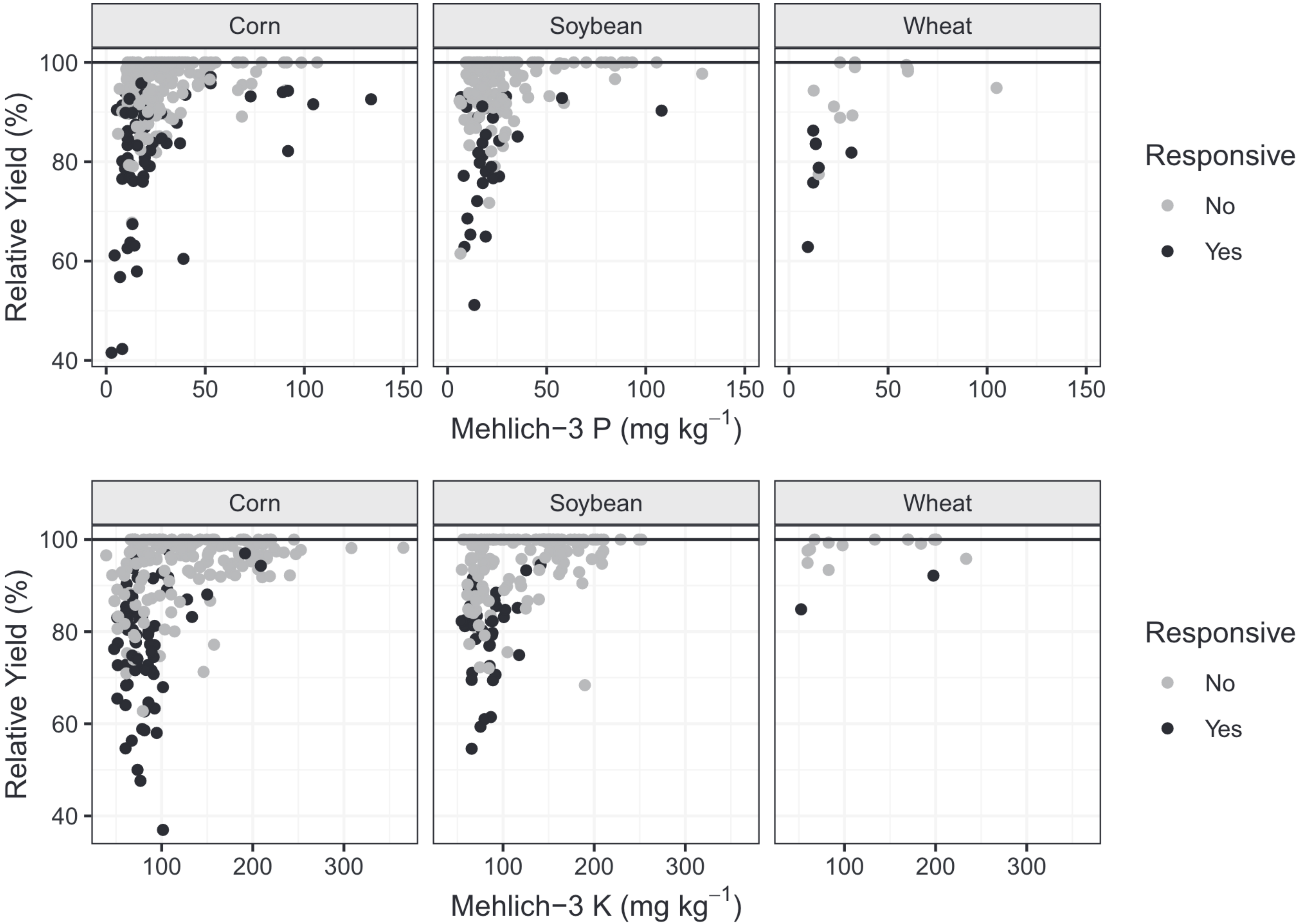
TABLE 2 Summary of grain yield responses for phosphorus and potassium trials across three datasets and by crop.

Nutrient	Dataset	Crop	Total trials	Responsive trials[a]	Response rate (%)	Average yield increase in responsive trials (Mg ha^{-1})	(%)	Average yield increase of all trials (Mg ha^{-1})	(%)
Phosphorus	D1	Corn	49	29	59.2	1.52	25.4	1.06	16.6
		Soybean	33	8	24.2	0.61	31.1	0.16	8.4
		Wheat	5	5	100.0	0.89	29.2	0.89	29.2
	D2	Corn	135	38	28.1	2.24	26.6	0.98	11.3
		Soybean	117	16	13.7	0.69	28.9	0.21	7.9
	D3	Corn	57	5	8.8	0.70	6.5	0.24	2.4
		Soybean	47	4	8.5	0.33	10.8	0.07	1.9
		Wheat	14	2	14.3	1.06	24.5	0.41	8.8
	Total		457	107	23.4	1.46	25.5	0.53	8.8
Potassium	D1	Corn	76	53	69.7	2.12	33.2	1.64	25.1
		Soybean	31	22	71.0	0.71	29.7	0.54	23.0
		Wheat	3	1	33.3	0.57	17.9	0.32	8.5
	D2	Corn	135	17	12.6	3.00	34.8	0.91	10.6
		Soybean	117	19	16.2	0.71	22.9	0.22	7.5
	D3	Corn	35	3	8.6	1.49	20.6	0.21	2.7
		Soybean	47	0	0.0	0.00	0.0	−0.02	−0.4
		Wheat	14	1	7.1	0.63	8.5	0.06	1.1
	Total		458	116	25.3	1.71	30.4	0.65	11.0

MaxRY =

(Unfertilized/
Max of all Trts)
x 100

Pearce et al., 2022



Percent Change = (Fertilized – Control)/ Control) x 100

75% P trials & 76% K trials were directionally positive

Compare to S grain yield response: 44% corn, 65% soybean, 50% wheat trials. (n=96) Fleuridor et al., (2023) AJ

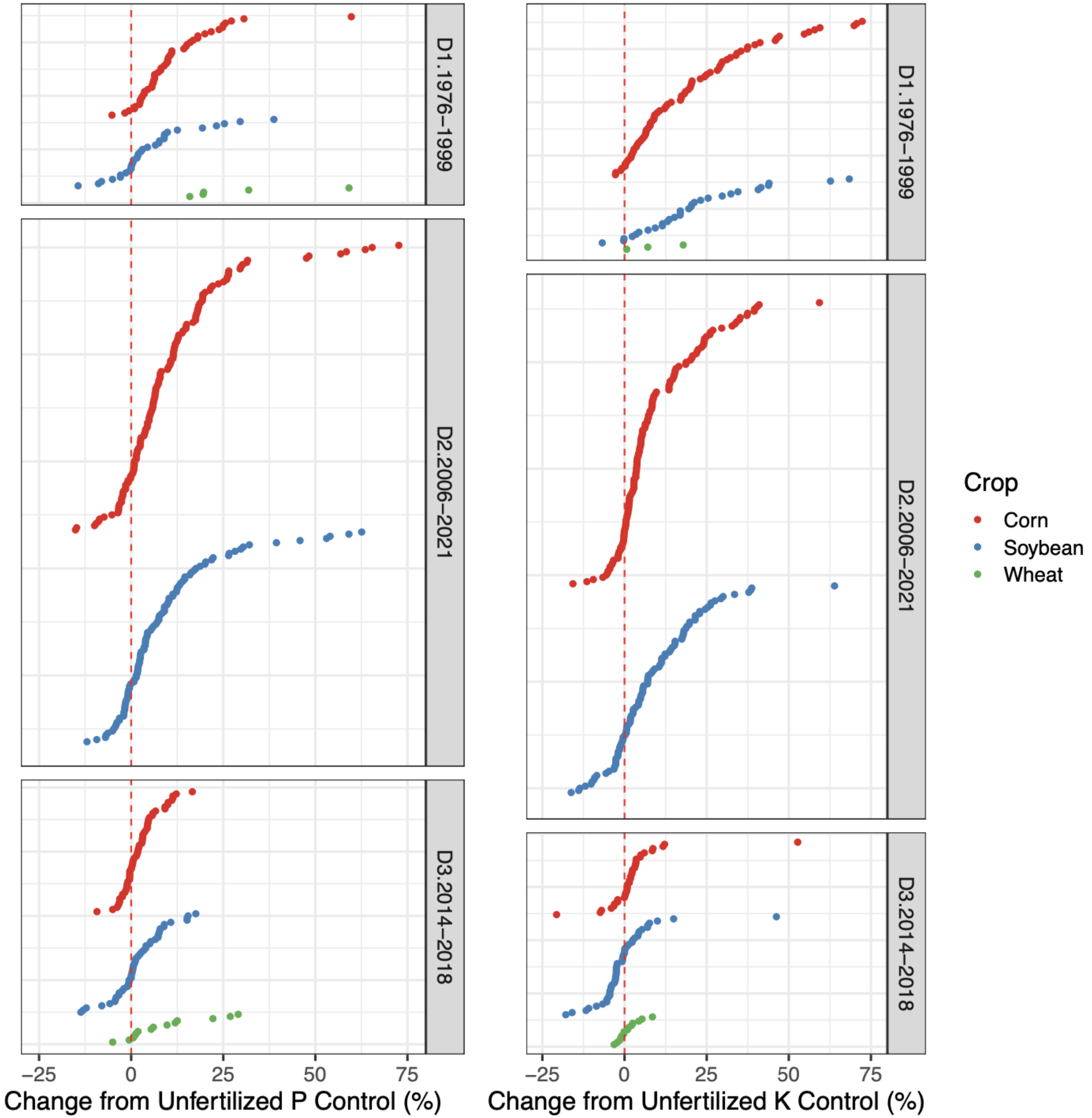


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TABLE 3 Model-selected Mehlich-3 critical soil test values for phosphorus and potassium trials derived (1) across all datasets and crops and (2) by crop and dataset individually.

Nutrient	Dataset	Crop	Cate–Nelson	Mitscherlich	Linear plateau	Quadratic plateau	Model average
Phosphorus			**Mehlich-3 P critical soil test value (mg kg^{-1})**				
	All	All	10	14	25	34	20
	All	Corn	11	15	25	31	20
	All	Soybean	9	11	40	54	29
	All	Wheat	32	18	36	43	32
	D1	All	11	12	19	15	14
	D2	All	13	15	21	27	19
	D3	All	15	10	33	44	26
Potassium			**Mehlich-3 K critical soil test value (mg kg^{-1})**				
	All	All	92	89	148	210	135
	All	Corn	92	107	139	214	138
	All	Soybean	105	91	150	216	141
	All	Wheat	60	54	61	64	60
	D1	All	106	149	192	.	149
	D2	All	77	87	140	199	126
	D3	All	51	44	76	94	66

Note: The four models included Cate–Nelson, Mitscherlich, linear plateau, and quadratic plateau models, with the average of all models also presented.

Bias in model-derived in CSTVs

- Similar bias is commonplace in studies that report multiple models
  - OK, NC, IA, TN & China (Antonangelo et al., 2019; Cox,1992; Dodd & Mallarino, 2005; Mallarino & Blackmer, 1992; Singh et al., 2019; Tang et al., 2009)
- Our model fits were poor
  - $R^2 < 0.35$ across all models
  - AIC and AIC_c were nearly identical across models
- Criteria to select most appropriate model?

Using model CSTVs to classify responsive trials

TABLE 4 The percentage of trials above the Mehlich-3 critical soil test value (CSTV), the percentage of responsive trials below the CSTV, and non-responsive trials above the CSTV for individual models and the average of all four models.

Nutrient	Model	Mehlich-3 CSTV (mg kg^{-1})	Trials above CSTV (%)	Responsive when below CSTV (%)	Not Responsive when above CSTV (%)
Phosphorus	Cate–Nelson	10	93.8	66.7	78.4
	Mitscherlich	14	77.4	43.4	81.2
	Linear plateau	25	41.2	32.9	87.8
	Quadratic plateau	34	22.8	27.1	85.0
	Model average	20	45.1	38.4	87.1
Potassium	Cate–Nelson	92	53.9	41.2	89.3
	Mitscherlich	89	56.5	41.0	87.7
	Linear plateau	148	28.2	33.2	96.7
	Quadratic plateau	210	5.3	26.2	100.0
	Model average	135	34.5	36.0	96.6

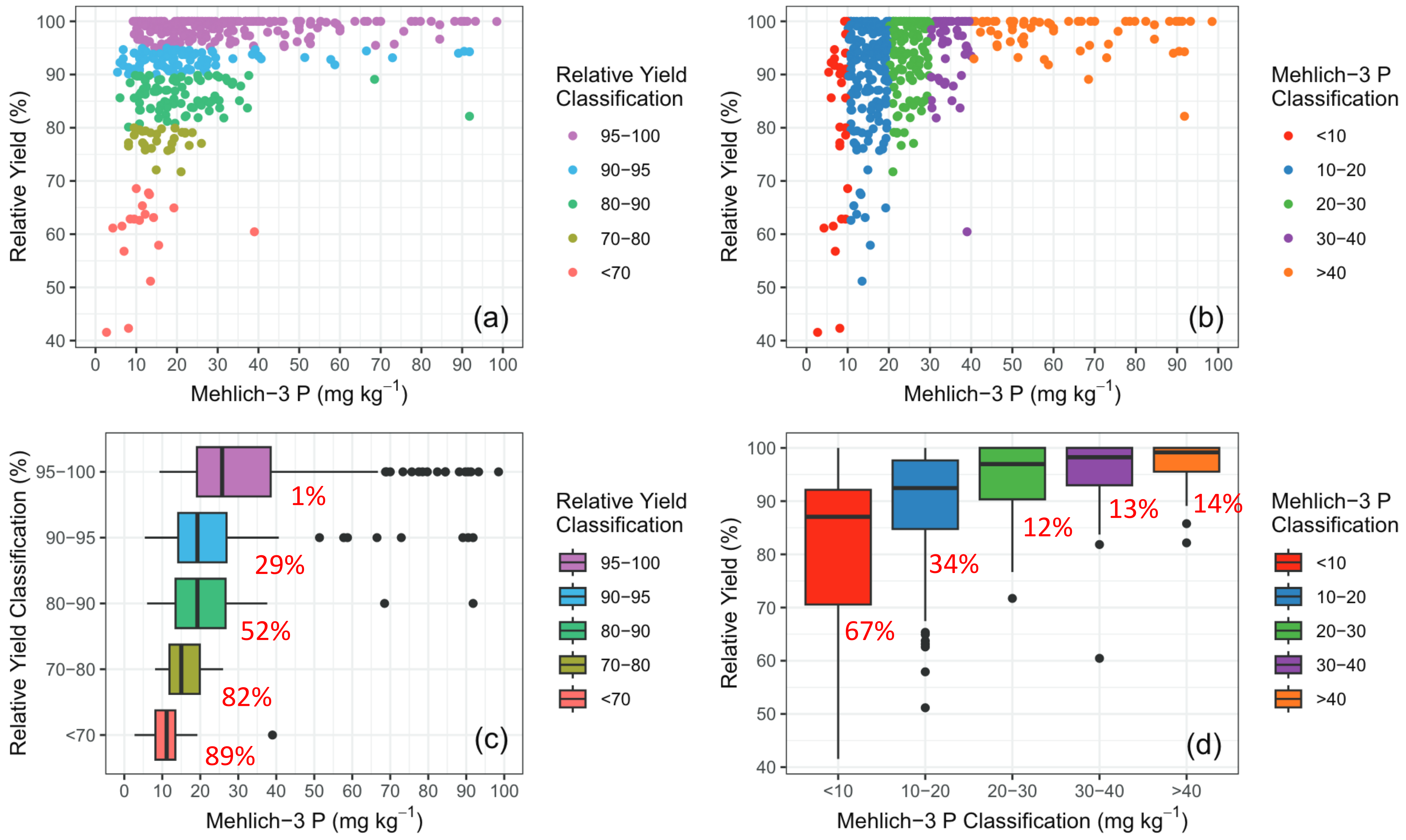
Nature of P and K Response Data

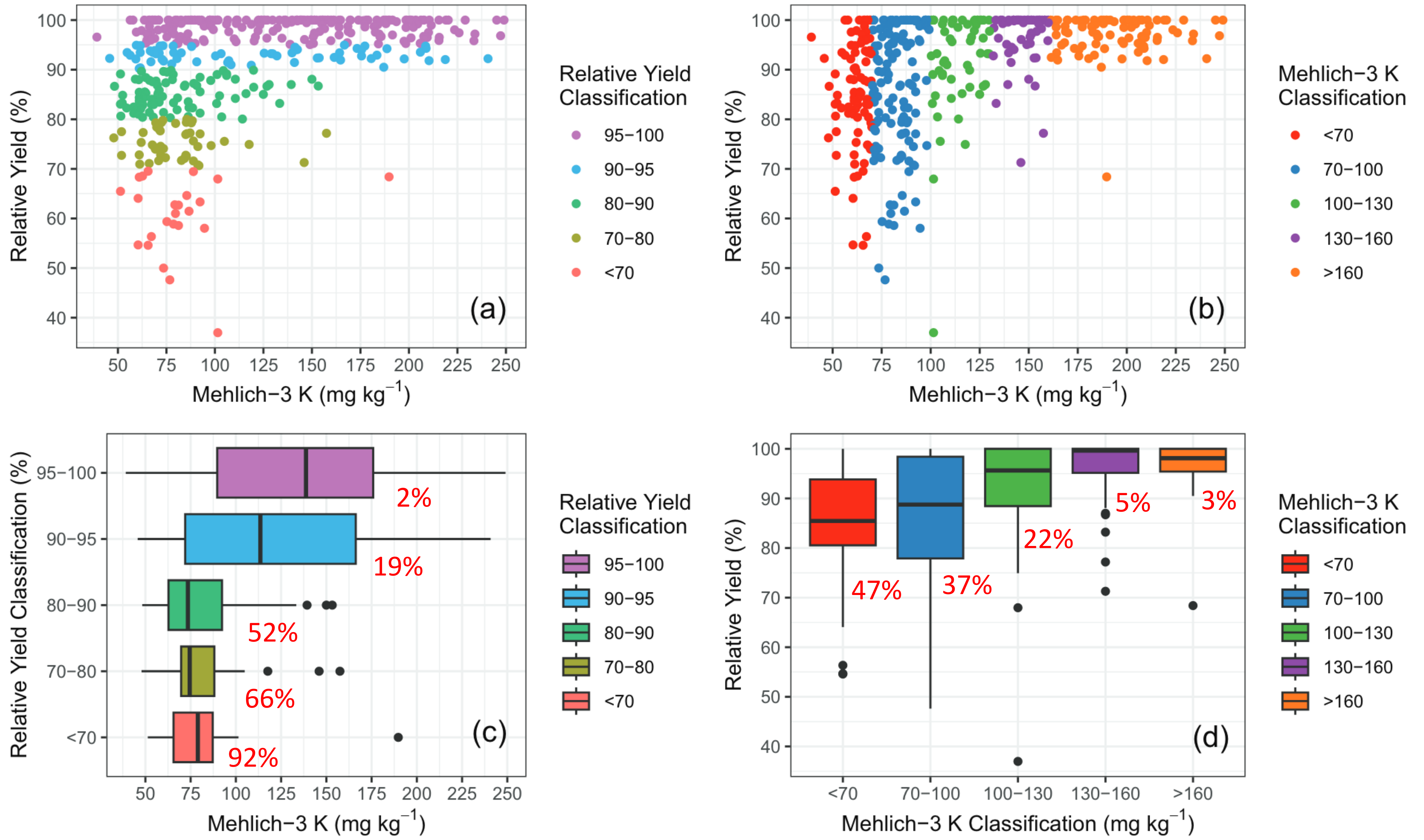
1. Responses to fertilization were generally infrequent (∼25% of trials for both P and K)

2. Responsive trials occurred across a range of soil test values, not exclusively at low soil test values

Trying a different approach…

responsive rates classified into discrete categories…
arbitrary, but intuitive!


Relative Yield (%)
Mehlich−3 P (mg kg−1)
Relative Yield Classification
95−100
90−95
80−90
70−80
<70
(a)
Mehlich−3 P Classification
<10
10−20
20−30
30−40
>40
(b)
Relative Yield Classification (%)
1%
29%
52%
82%
89%
(c)
Mehlich−3 P Classification (mg kg−1)
67%
34%
12%
13%
14%
(d)



Relative Yield (%)
Mehlich−3 K (mg kg^{-1})
Relative Yield Classification
95−100
90−95
80−90
70−80
<70
(a)
Mehlich−3 K Classification
<70
70−100
100−130
130−160
>160
(b)
Relative Yield Classification (%)
2%
19%
52%
66%
92%
(c)
47%
37%
22%
5%
3%
(d)
Mehlich−3 K Classification (mg kg^{-1})

Study Conclusions

- 457 P and 458 K trials, fertilizer increased yields ~10% in ~25% of trials

- General relationships between soil test levels and yield response, but…
  - Models were weak, robust CSTVs were not identified
  - Model-derived bias was systematic and consistent
  - Evaluation criteria for model fit provided little insight
  - No scientific consensus regarding objective criteria to select models

- Rather than finding binary CSTV, discrete classifications were fruitful
  - >20 mg kg^{-1} M3P: < 15% chance of yield response to P
  - >130 mg kg^{-1} M3K: < 5% chance of yield response to K

Discussion Questions for FRST Scientists

- Should we strive for a critical soil test value in P and K response trials?
  - Is this the 'right' approach?
- If so, what are the (objective) criteria to evaluate model fit?
- Do farmers/ nutrient management providers conceptualize fertilizer need as binary? Yes/no?
  - Or more in lines with risk/reward, likelihood of response? Likelihood of ROI?