



Alfalfa Response to Phosphorus and Potassium in Association with Calcium and Magnesium and Harvest Time

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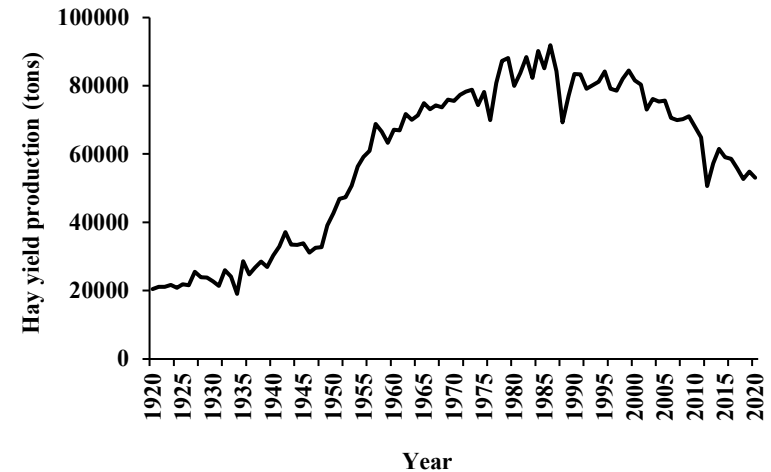
Background

- ❑ Productive and profitable forage system
 - ✓ Alfalfa (*Medicago sativa* L.)
 - ✓ Exceptional productivity potential

- ❑ Decline in alfalfa acreage (Russelle, 2017)

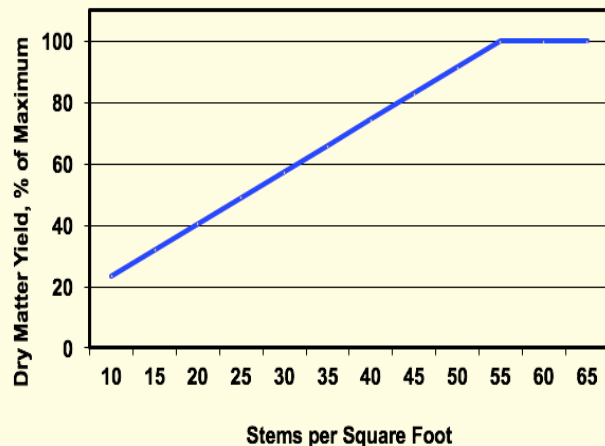
- ❑ Stand Management

US Alfalfa hay production (1920-2020)



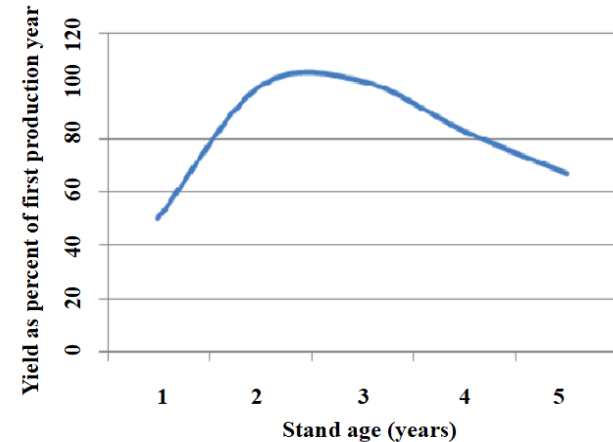
(USDA-NASS, 2021)

Alfalfa stem count and yield potential



(Undersander *et al.*, 2011)

Effect of stand age on yield



(Undersander and Barnett, 2008)



Background

□ Agronomic management practices

- ✓ Replacement of nutrient in the forage
- ✓ Cutting schedules
- ✓ Crop genetics (cultivar)
- ✓ Insect, disease and weed control

□ Balanced nutrition

- ✓ Phosphorus (P) and K

□ Current soil fertility status

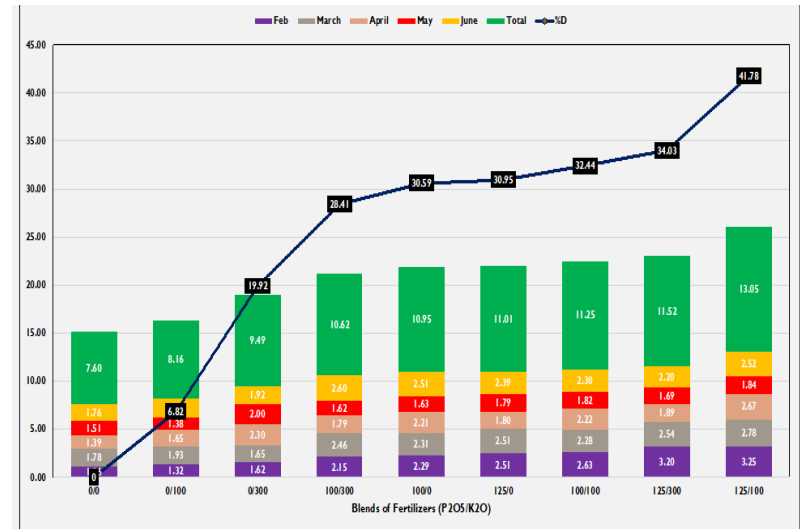
- ✓ Nutrient availability and uptake

□ Soil pH

- ✓ P availability and uptake
 - P, Ca and/or Mg (Jeschke, 2017)

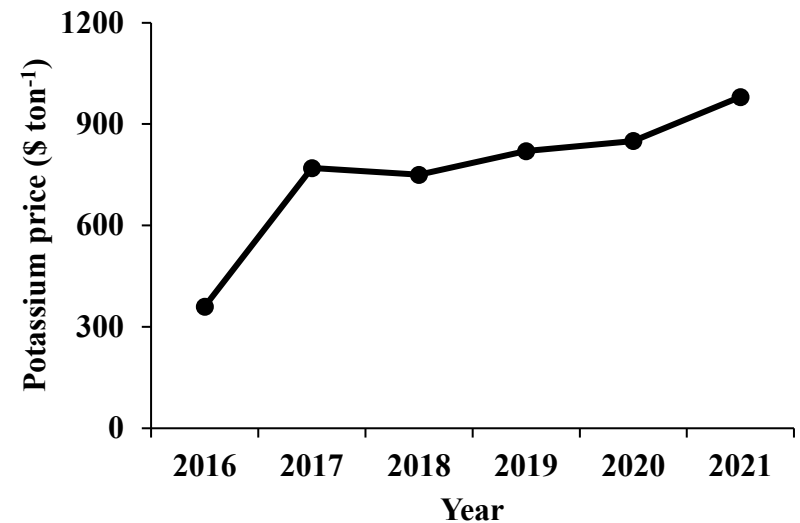
□ Valency effect

- ✓ K availability and uptake
 - K^+ , Ca^{+2} , and Mg^{+2} (Laekemariam *et al.*, 2018)



Percent yield increase (%D) due to P & K treatments over untreated control ranged from 6.82 to 41.78%

(Burayu and Mostafa, 2020)



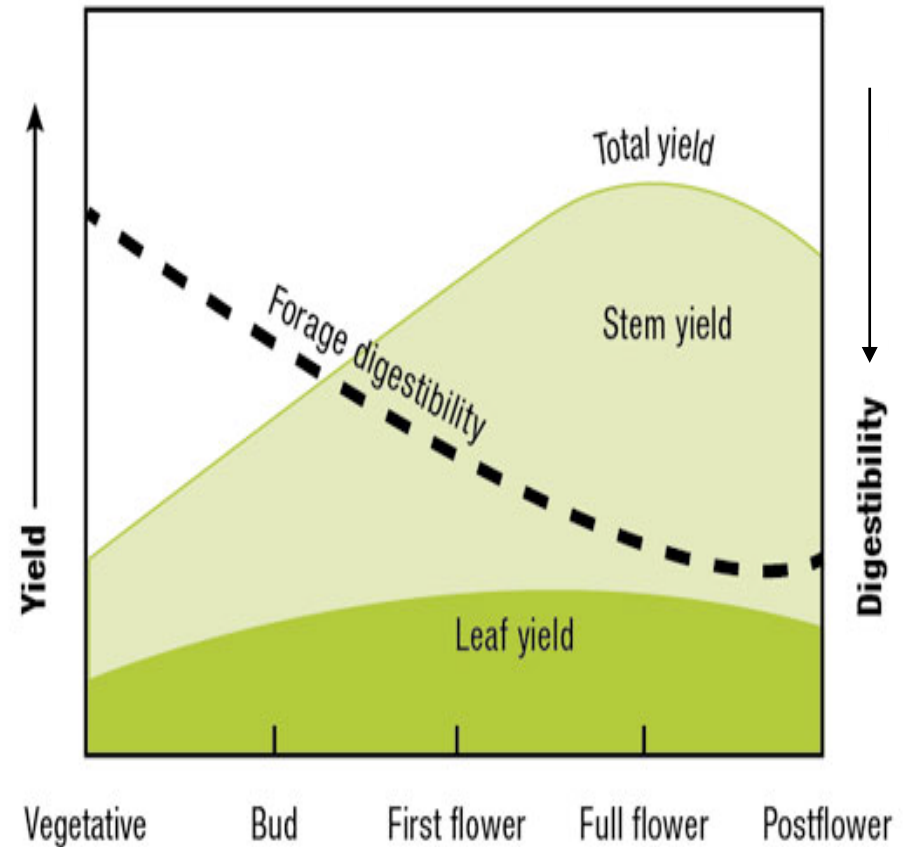
(US Geological Survey, 2022)



Background

- ❑ P and K combinations
 - ✓ Interact with other soil nutrients (IPNI, 1998)
- ❑ Soils high in Mg and Ca
 - ✓ P and K availability and uptake?
- ❑ Time of harvest
 - ✓ Critical to alfalfa's productivity
- ❑ Alfalfa's response
 - ✓ P and K combination
 - ✓ Mg and Ca
 - ✓ Harvest time

Yield and Quality trade-off in alfalfa



Questions

- Will alfalfa respond to P and K nutrition in soil with high K levels?
- Will alfalfa respond to P and K nutrition in soil with high Ca and Mg levels?
- What will be the effect of P and K combination in association with Ca, Mg, and harvest time on alfalfa production?



Goal

- ❑ Determine whether P, K, Ca, Mg, and harvest time interaction will affect forage accumulation, nutritive value, and stand persistence of alfalfa

Hypothesis

- ❑ The interactions among P, K, Ca, Mg, and harvest time management will have a significant positive effect on alfalfa production

Specific objective

- ❑ Evaluate the interaction effect of P and K along with Ca, Mg, and harvest time on productivity and profitability of alfalfa



Approach

- ❑ Experimental site
 - ✓ SAREC

- ❑ Treatments
 - ✓ 18 P, K, Ca, and Mg combinations
 - 3 P rates: (0, 34, and 67 kg P₂O₅ ha⁻¹)
 - 3 K rates: (0, 168, and 336 kg K₂O ha⁻¹)
 - 2 Ca rates: (0 and 560 kg CaO ha⁻¹)
 - 2 Mg rates: (0 and 56 kg MgO ha⁻¹)

 - ✓ 2 Harvest times
 - Early harvest (late bud to early [10%] bloom)
 - Late harvest (7 days after early harvest)

- ❑ Experimental design
 - ✓ Factorial arrangement in RCBD
 - ✓ 3 replications



P, K, Ca, and Mg combination rates

T ₁ : P ₀ K ₀ Ca ₀ Mg ₀	T ₁₀ : P ₀ K ₀ Ca ₅₆₀ Mg ₅₆
T ₂ : P ₀ K ₁₆₈ Ca ₀ Mg ₀	T ₁₁ : P ₀ K ₁₆₈ Ca ₅₆₀ Mg ₅₆
T ₃ : P ₀ K ₃₃₆ Ca ₀ Mg ₀	T ₁₂ : P ₀ K ₃₃₆ Ca ₅₆₀ Mg ₅₆
T ₄ : P ₃₄ K ₀ Ca ₀ Mg ₀	T ₁₃ : P ₃₄ K ₀ Ca ₅₆₀ Mg ₅₆
T ₅ : P ₃₄ K ₁₆₈ Ca ₀ Mg ₀	T ₁₄ : P ₃₄ K ₁₆₈ Ca ₅₆₀ Mg ₅₆
T ₆ : P ₃₄ K ₃₃₆ Ca ₀ Mg ₀	T ₁₅ : P ₃₄ K ₃₃₆ Ca ₅₆₀ Mg ₅₆
T ₇ : P ₆₇ K ₀ Ca ₀ Mg ₀	T ₁₆ : P ₆₇ K ₀ Ca ₅₆₀ Mg ₅₆
T ₈ : P ₆₇ K ₁₆₈ Ca ₀ Mg ₀	T ₁₇ : P ₆₇ K ₁₆₈ Ca ₅₆₀ Mg ₅₆
T ₉ : P ₆₇ K ₃₃₆ Ca ₀ Mg ₀	T ₁₈ : P ₆₇ K ₃₃₆ Ca ₅₆₀ Mg ₅₆



Approach

- ❑ Initial soil analysis (0-15 cm depth)

- ❑ Initial fertilization
 - ✓ P & K (Aug 30, 2019)
 - ✓ Ca & Mg (Dec 23, 2019)

- ❑ Planting
 - ✓ Hi-Gest 360 alfalfa
 - ✓ Seeding rate: 22 kg pure live seed ha⁻¹



Data collection and analysis

- Forage dry matter
- Leaf to stem ratio
- Nutritive value
- Economics

Harvest dates

Harvest	2020		2021	
	Early harvest	Late harvest	Early harvest	Late harvest
One	Jun 10	Jun 17	Jun 17	Jun 24
Two	Jul 10	Jul 17	Jul 16	Jul 23
Three	Aug 10	Aug 17	Aug 18	Aug 25
Four	Sept 17	Sept 24	Sept 16	Sept 23



- ANOVA (SAS 9.4)
 - ✓ PROC MIXED
 - Post-Hoc : LSD (0.05)



Results and Discussion

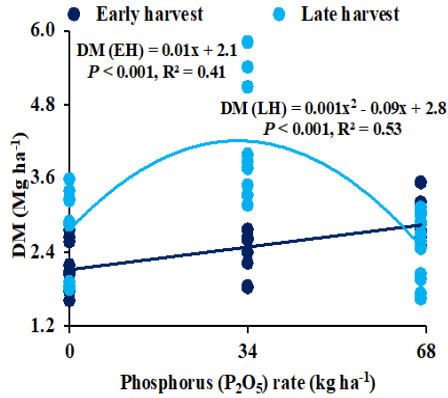
Initial soil test results in 2019

Soil property	Test results
pH (1:1)	8.3
Organic matter (%)	1.91
Nitrate-N (mg kg ⁻¹)	29
Phosphorus (mg kg ⁻¹)	9.7
Potassium (mg kg ⁻¹)	243
Calcium (mg kg ⁻¹)	3526
Magnesium (mg kg ⁻¹)	328
Sulphur (mg kg ⁻¹)	43
Sodium (mg kg ⁻¹)	63
Cation Exchange Capacity (meq [100g] ⁻¹)	22

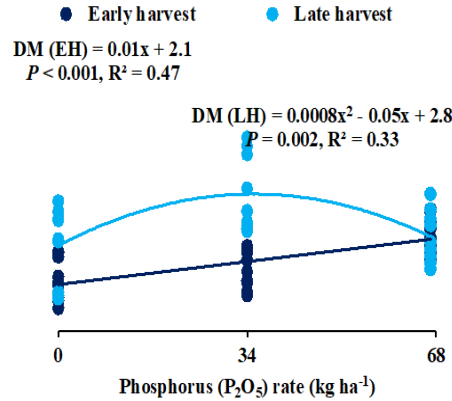


Forage yield (DM; 2-yr avg)

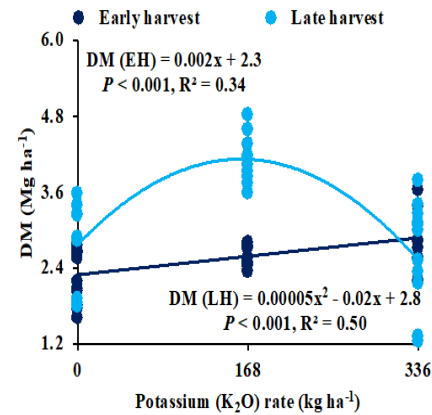
Without Ca₅₆₀Mg₅₆



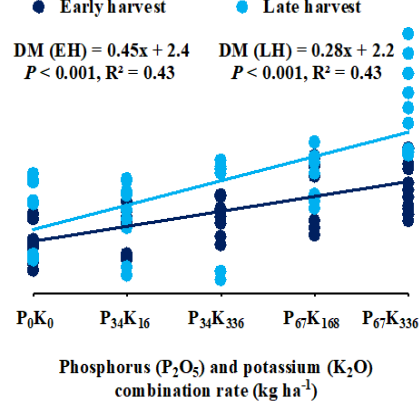
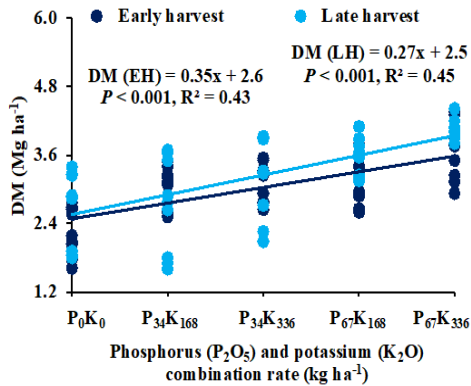
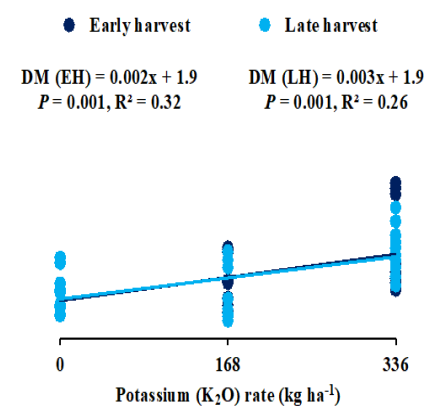
With Ca₅₆₀Mg₅₆



Without Ca₅₆₀Mg₅₆



With Ca₅₆₀Mg₅₆



Forage yield (2-yrs total and percent yield increase)

Treatment (kg ha ⁻¹)	Early harvest		Late harvest	
	Total yield	% increase	Total yield	% increase
	(Mg ha ⁻¹)		(Mg ha ⁻¹)	
P ₀ K ₀	16.0 g	-	16.4 h	-
P ₃₄	16.8 fg	5	22.0 bc	34
P ₆₇	17.6 ef	10	17.6 g	7
K ₁₆₈	18.4 e	14	22.4 bc	37
K ₃₃₆	20.0 cd	24	18.8 ef	15
P ₃₄ K ₁₆₈	21.2 bc	33	20.4 cd	24
P ₃₄ K ₃₃₆	21.4 b	33	22.2 b	35
P ₆₇ K ₁₆₈	21.4 b	33	21.4 b	30
P ₆₇ K ₃₃₆	22.6 a	41	22.8 b	38
Ca ₅₆₀ Mg ₅₆	18.4 e	15	18.8 ef	14
P ₃₄ Ca ₅₆₀ Mg ₅₆	16.6 f	3	20.6 cd	26
P ₆₇ Ca ₅₆₀ Mg ₅₆	20.2 c	26	19.6 de	19
K ₁₆₈ Ca ₅₆₀ Mg ₅₆	17.4 e	9	18.8 ef	16
K ₃₃₆ Ca ₅₆₀ Mg ₅₆	19.0 de	19	18.0 fg	10
P ₃₄ K ₁₆₈ Ca ₅₆₀ Mg ₅₆	19.6 d	22	17.8 fg	8
P ₃₄ K ₃₃₆ Ca ₅₆₀ Mg ₅₆	18.6 de	16	21.4 bc	30
P ₆₇ K ₁₆₈ Ca ₅₆₀ Mg ₅₆	21.4 b	34	20.2 c	23
P ₆₇ K ₃₃₆ Ca ₅₆₀ Mg ₅₆	21.2 b	33	25.0 a	52



Nutritive Value and Leaf to Stem Ratio

Treatment kg ha ⁻¹	CP	NDF	ADF	TDN	IVDMD	RFV	Leaf : Stem
	----- g kg ⁻¹ -----						
P ₀ K ₀	279	320	252	741	813	205	39
P ₃₄	275	323	255	739	816	203	33
P ₆₇	268	308	254	740	808	213	35
K ₁₆₈	270	328	261	732	802	198	37
K ₃₃₆	272	321	259	734	809	202	34
P ₃₄ K ₁₆₈	268	320	260	732	806	203	34
P ₃₄ K ₃₃₆	280	314	252	742	822	210	34
P ₆₇ K ₁₆₈	277	318	252	741	817	206	42
P ₆₇ K ₃₃₆	277	323	258	735	817	204	37
Ca ₅₆₀ Mg ₅₆	270	324	260	733	810	201	39
P ₃₄ Ca ₅₆₀ Mg ₅₆	277	305	245	749	817	217	31
P ₆₇ Ca ₅₆₀ Mg ₅₆	266	326	262	731	809	199	38
K ₁₆₈ Ca ₅₆₀ Mg ₅₆	276	310	253	740	818	210	36
K ₃₃₆ Ca ₅₆₀ Mg ₅₆	274	318	255	738	818	206	37
P ₃₄ K ₁₆₈ Ca ₅₆₀ Mg ₅₆	269	327	261	732	813	198	41
P ₃₄ K ₃₃₆ Ca ₅₆₀ Mg ₅₆	272	319	256	737	813	204	34
P ₆₇ K ₁₆₈ Ca ₅₆₀ Mg ₅₆	275	320	259	734	813	208	37
P ₆₇ K ₃₃₆ Ca ₅₆₀ Mg ₅₆	271	328	261	731	811	199	35
Average	273	320	256	737	813	205	36
<i>P</i> -value	0.546	0.580	0.778	0.778	0.556	0.486	0.772
Harvest time							
Early harvest	272	310	257	736	812	209	35
Late harvest	274	329	256	737	814	200	37
Average	273	320	256	737	813	205	36
<i>P</i> -value	0.424	< 0.001	0.778	0.694	0.442	0.001	0.186

Economic analysis

Input and output costs	2020	2021
Land preparation (\$ ha ⁻¹)	199	0
Soil test (\$ per sample)	12	0
Seed and seeding (\$ ha ⁻¹)	47	0
Potassium (\$ kg ⁻¹)	0.88	0.92
Fertilizer application (\$ ha ⁻¹)	16	16
Irrigation (\$ ha-mm ⁻¹)	1.1	1.1
Land rental (\$ ha ⁻¹)	200	203
Baling and Hauling (\$ ha ⁻¹)	19	22
Mowing and raking (\$ ha ⁻¹)	57	55
Production cost (\$ ha⁻¹)	359	355
Cost of capital (5%)	18	18
Total production cost (\$ ha⁻¹)	377	372
Hay price (\$ kg⁻¹)	0.20	0.23
Expected revenue (\$ ha⁻¹)	585	554
Profit margin (\$ ha⁻¹)	208	182

❑ Inflation of input and output costs

✓ Producer price index

❑ Hay price

✓ Supreme hay quality
(USDA-NASS, 2022)

❑ Revenue = Hay price * DM

❑ Profit = Revenue – Total cost



Alfalfa fertilized with P and K in association with Ca and Mg (2-yrs total)

Treatment (kg ha ⁻¹)	Total production cost (\$ ha ⁻¹)	Total revenue (\$ ha ⁻¹)	Profit margin (\$ ha ⁻¹)
P ₀ K ₀	2084h	3358i	1274efg
P ₃₄	2177h	4062defgh	1885ab
P ₆₇	2135h	3667hi	1532d
K ₁₆₈	2473fg	4301bcdef	1829abc
K ₃₃₆	2710de	4049defgh	1339efg
P ₃₄ K ₁₆₈	2513f	4367abcde	1854ab
P ₃₄ K ₃₃₆	2857cd	4635abc	1778abcd
P ₆₇ K ₁₆₈	2543ef	4493abcd	1950a
P ₆₇ K ₃₃₆	2874bcd	4717ab	1844ab
Ca ₅₆₀ Mg ₅₆	2381g	3923efgh	1542d
P ₃₄ Ca ₅₆₀ Mg ₅₆	2397g	3885gh	1488def
P ₆₇ Ca ₅₆₀ Mg ₅₆	2461f	4023efgh	1563cd
K ₁₆₈ Ca ₅₆₀ Mg ₅₆	2652ef	3795ghi	1143g
K ₃₃₆ Ca ₅₆₀ Mg ₅₆	2997abc	3821gh	824h
P ₃₄ K ₁₆₈ Ca ₅₆₀ Mg ₅₆	2703de	3906fgh	1203fg
P ₃₄ K ₃₃₆ Ca ₅₆₀ Mg ₅₆	3049ab	4221cdefg	1173g
P ₆₇ K ₁₆₈ Ca ₅₆₀ Mg ₅₆	2781de	4355abcdef	1575cd
P ₆₇ K ₃₃₆ Ca ₅₆₀ Mg ₅₆	3148a	4795a	1647bcd



Summary

- ❑ **Improved productivity and profits**
 - ✓ **Balanced P and K rates**

 - ✓ **Harvest time influenced P and K**
 - **High P and K rates, and early harvest**
 - **Moderate P and K rates, and late harvest**

 - ✓ **High P × K rates**
 - **Both harvest times**

 - ✓ **Soils with high K relative to Ca and Mg**



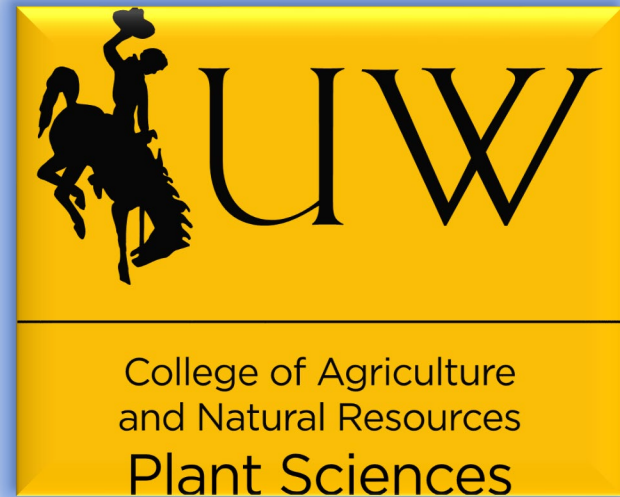
Recommendation

- ❑ **Update existing K fertility guide**
 - ✓ **Along with soil test results**



Acknowledgment

- Mr. Chandan Shilpakar
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- Mr. Kevin Madden and SAREC crew
- Alforex seeds company



Thank You