Potassium Accumulation and Partitioning in Three Soybean Genotypes Differing in Maturity Group

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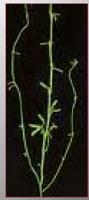
Introduction

Understanding the uptake and distribution pattern of nutrients among plant structures during the growing season is required to develop sound fertilization programs and diagnostic information to assess plant nutritional health. The relationship between soybean [*Glycine max* (L.) Merr.] trifoliolate leaf potassium (K) concentration and seed yield may be different for determinate and indeterminate soybean varieties due to the longer flower and pod set periods of indeterminate varieties coupled with the competition for nutrients between the vegetative and reproductive structures (Egli and Leggett, 1973). If so, it is reasonable to assume that dry matter and K accumulation and distribution, critical leaf K concentration, the proper plant part to sample for tissue analysis, and the best plant development stage for sample collection could differ between growth habits.

Our objective was to evaluate season-long dynamics of dry matter accumulation and K uptake and allocation to aboveground plant parts in representative determinate and indeterminate soybean varieties of different maturity groups (MG) under the same growing condition.

Materials and Methods

- **Experimental site in 2012 and 2013**
  - Pine Tree Research Station (Colt, AR)
  - Calhoun silt loam (pH 7.2)
- **Seeded on 22 May 2012 and 26 June 2013**
  - Soybean emerged 7 d after seeding
- **Three glyphosate-resistant soybean varieties**
  - Armor 39-R16 (MG 3.9; Indeterminate; 2012 & 2013)
  - Armor 48-R40 (MG 4.7; Indeterminate; 2012 & 2013)
  - Armor 53-R15 (MG 5.3; Determinate; 2012)
  - Armor 55-R22 (MG 5.5; Determinate; 2013)
- **Plant sampling and analysis**
  - Plant population: Thinned to 15 plants 1.2 m^{-1} linear row
  - Sampling time: 8 (2012) to 10 (2013) at 10 to 14 d interval
  - Trifoliolate leaves: 12 leaves from any of the top 3 nodes
  - Recording growth stage: According to Fehr et al. (1971)
  - Partitioning: Leaves, petioles, stems, pods, and seeds
  - K concentration: Digestion and analysis by ICP-AES
- **Parameters measurement**
  - Aboveground dry matter and K accumulation
  - Predicted crop growth rate and K uptake rate
  - Dry matter and K distribution among plant parts
  - Trifoliolate leaf K concentration
- **Statistical analysis (JMP Pro 11)**
  - Data from 2012 and 2013 were analyzed separately due to the large difference in planting date and duration of growing season.
  - Linear regression: Trifoliolate K concentration from R1 or R2 to R7
  - Non-linear regression (Archontoulis and Miguez, 2013)
    - ✓ Gaussian peak model: Dry matter accumulation; K uptake; dry matter and K distribution among leaves, petioles, and stems; and trifoliolate leaf K concentration
    - ✓ Gompertz model: Dry matter and K distribution in beans (pod+seed)



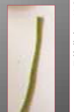


Fig. 1. Dry matter accumulation of three soybean varieties from different maturity groups (MG) in 2012. Model coefficients are listed in Table 1.

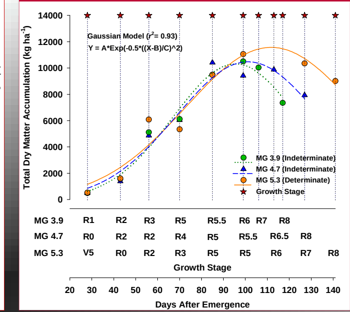


Fig. 2. Potassium uptake of three soybean varieties from different maturity groups (MG) in 2012. Model coefficients are listed in Table 1.

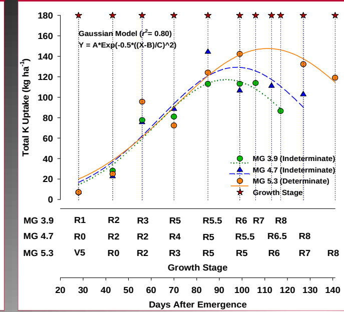


Fig. 3. Predicted crop growth rate of three soybean varieties from different maturity groups (MG) in 2012.

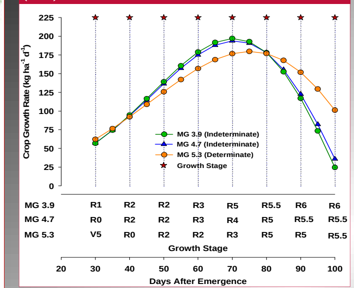


Fig. 4. Predicted K uptake rate of three soybean varieties from different maturity groups (MG) in 2012.

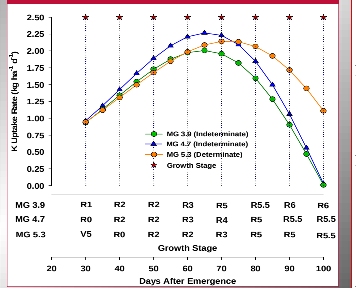


Fig. 5. Dry matter distribution of the maturity group 4.7 soybean variety in 2012 as predicted with Gaussian model for leaf, petiole, and stem, and Gompertz model for bean (pod+seed).

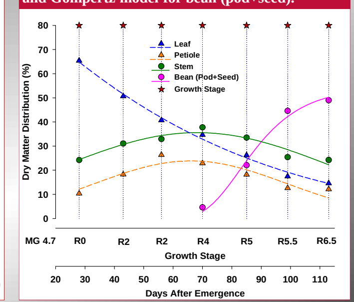


Fig. 6. Potassium distribution of the maturity group 4.7 soybean variety in 2012 as predicted with Gaussian model for leaf, petiole, and stem, and Gompertz model for bean (pod+seed).

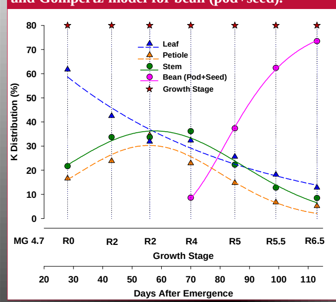


Fig. 7. Change in trifoliolate leaf K concentration in three soybean varieties from different maturity groups (MG) in 2012. Model coefficients are listed in Table 1.

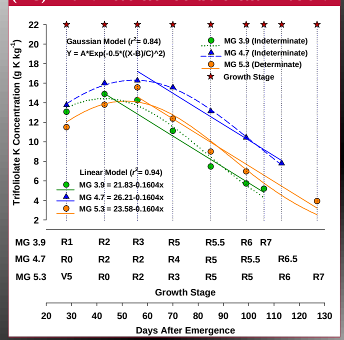


Table 1. Model coefficients for the Gaussian peak model† (2012 data) for predicting dry matter and K accumulation and trifoliolate leaf K concentration.

MG‡	A	B	C	r^2	*P*-value
Fig. 1. Dry matter accumulation of three maturity groups					
MG 3.9	10318 a	96 a	28.6 c	0.95	<0.001
MG 4.7	10475 a	101 a	32.7 b	0.92	<0.001
MG 5.3	11572 a	112 a	39.0 a	0.90	<0.001
Fig. 2. Potassium uptake of three maturity groups					
MG 3.9	118 a	93 b	31.9 c	0.84	<0.001
MG 4.7	129 a	98 b	34.5 b	0.78	<0.001
MG 5.3	148 a	111 a	41.7 a	0.79	<0.001
Fig. 7. Trifoliolate K concentration of three maturity groups					
MG 3.9	14.4 ab	43 c	40.6 b	0.82	<0.001
MG 4.7	16.3 a	55 a	47.2 a	0.86	<0.001
MG 5.3	14.2 b	51 b	40.8 b	0.79	<0.001

†In Gaussian model, the coefficient 'A' is the peak value (kg ha^{-1} or g kg^{-1}), 'B' is the critical point (DAE), and 'C' is the value that controls the width of the bell shaped curve.
‡Maturity group; MG 3.9 and 4.7 are indeterminate varieties and 5.3 is determinate variety.

Results

Dry Matter Accumulation

- In 2012, the maximum dry matter accumulation for all three varieties was similar ranging from 10,318 to 11,572 kg ha^{-1} (Fig. 1; Table 1). In 2013, aboveground dry matter was similar for both indeterminate varieties (7,461 to 8,000 kg ha^{-1}) but different from the determinate variety (9,679 kg ha^{-1}).
- Regardless of growth habit or maturity group, dry matter accumulation peaked at R6.0-6.5 stage, which occurred at 96 to 102 DAE in 2012 and 82 to 96 DAE in 2013.

Potassium Uptake

- Aboveground K uptake was similar among varieties ranging from 118 to 148 (2012; Fig. 2; Table 1) and 125 to 132 (2013) kg K ha^{-1} but peak accumulation occurred at different DAE.
- Potassium uptake for all three varieties peaked at R5.5-6.0 stage, which occurred at 74 to 78 (2013) and 93 to 98 (2012) DAE for the MG 3.9 and 4.7 varieties, and 94 (2013) and 111 (2012) DAE for the MG 5.3 or 5.5 variety.

Crop Growth Rate

- The predicted rate of maximum crop growth occurred at R4-5 stage for all three varieties ranging from 180 to 197 kg ha^{-1} d^{-1} in 2012 (Fig. 3) and 144 to 167 kg ha^{-1} d^{-1} in 2013.

Potassium Uptake Rate

- The predicted rate of maximum aboveground K uptake occurred at R3-4 stage for all three varieties ranging from 2.01 to 2.27 (2012; Fig. 4) and 1.77 to 2.39 (2013) kg K ha^{-1} d^{-1}.

Dry Matter Distribution

- The three soybean varieties showed a similar trend in dry matter distribution. At the R6.0-6.5 stage, the time of maximum dry matter accumulation, the beans, stems, leaves, and petioles of the MG 4.7 variety accounted for an average of 49, 25, 14, and 12% of the dry matter, respectively (Fig. 5).

Potassium Distribution

- Potassium distribution pattern was similar for all three varieties. At the R5.5-6.0 stage, the total plant K distribution among plant parts of the MG 4.7 variety was 18% in the leaves, 7% in the petioles, 13% in the stems, and 62% in the beans (Fig. 6).

Trifoliolate Leaf K Concentration

- In 2012, trifoliolate leaf K concentration peaked at R2 stage (14.2-16.3 g K kg^{-1}) for all three varieties and declined linearly at a rate of 0.16 g K kg^{-1} d^{-1} until leaf senescence (R7; Fig. 7; Table 1). In 2013, trifoliolate K concentration peaked at R1 stage (19.8-20.6 g K kg^{-1}) and declined linearly, but the decline rate differed among varieties (0.06-0.21 g K kg^{-1} d^{-1}).

Practical Application

Knowledge of the dry matter and K accumulation pattern among soybean plant parts of both determinate and indeterminate varieties would be of value for developing diagnostic tissue sampling protocols to monitor the nutritional status of soybean. Further diagnostics for interpreting the change of soybean trifoliolate leaf K concentration across a range of K availability would enable assessment of the plant's K nutritional status at stages other than R2. The dry matter and K accumulation pattern suggests that K deficiency of soybean could possibly be corrected by timely fertilization during early reproductive growth.

Acknowledgments

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References

Archontoulis, S.V., and F.E. Miguez. 2013. Nonlinear regression models and applications in agricultural research. Agron. J. 105:1-13.

Egli, B.D., and J.E. Leggett. 1973. Dry matter accumulation patterns in determinate and indeterminate soybeans. Crop Sci. 13:220-222.

Fehr, W.R., C.E. Caviness, D.T. Burmood, and J.S. Pennington. 1971. Stage of development descriptions for soybeans [*Glycine max* (L.) Merr.]. Crop Sci. 11:929-931.