PRECISION, QUANTITATIVE MEASUREMENT OF SUNFLOWER CAPITULUM INCLINATION: A TRIGONOMETRY-BASED APPROACH

Emily DeValk

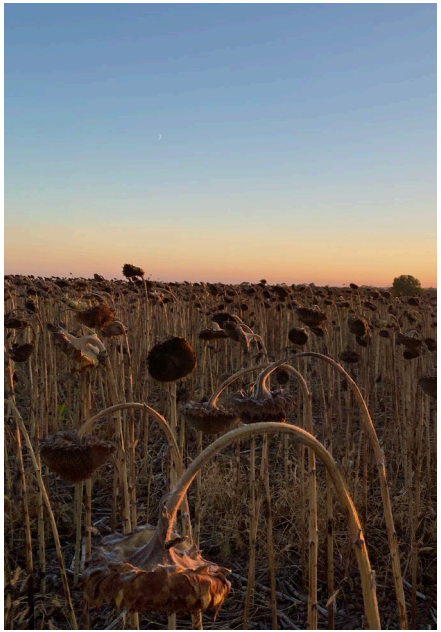
MS Student, North Dakota State University

NDSU NORTH DAKOTA STATE UNIVERSITY

Sunflower Head Inclination

- Drooping of the head as the plant matures
- Plant height, head size and weight, various stem traits
- Ranges from plant standing fully vertical to one that snaps and hangs down (kinked)

Sunflower Head Inclination



Ideal: 120° - 180°

Not Ideal: 0°

Not Ideal: Kinked

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Measuring Inclination Angle

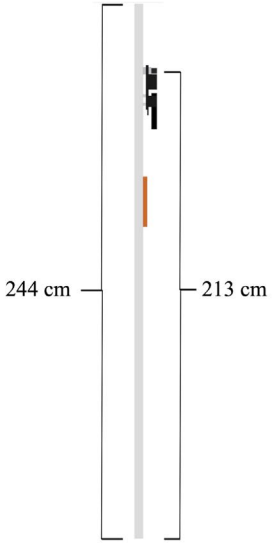
Until now, no precise way to measure

Plant Material

- Early maturity hybrid yield trial
  - Plot dimensions 5’ by 20’, two rows
  - 275 plots – 2022, 351 plots – 2023
  - Hybrids and commercial checks
  - Full variation in head inclination angle

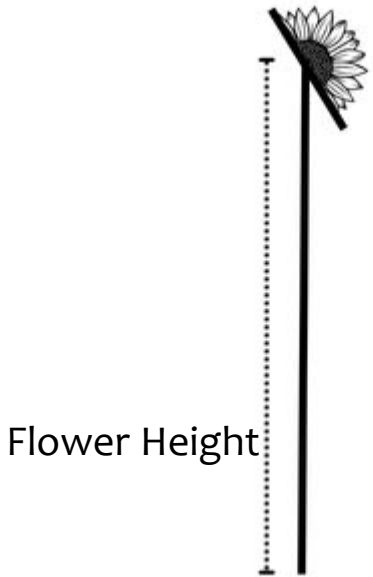
Data Collection

Collected data using modified height stick



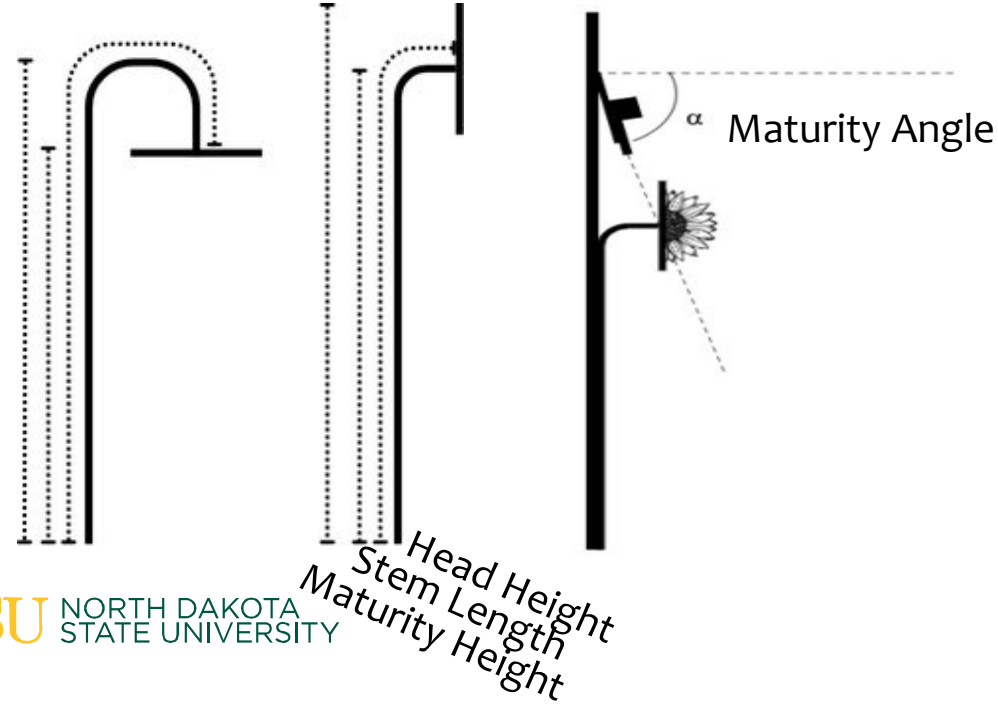
Data Collection

At peak flower (3 plants per plot)



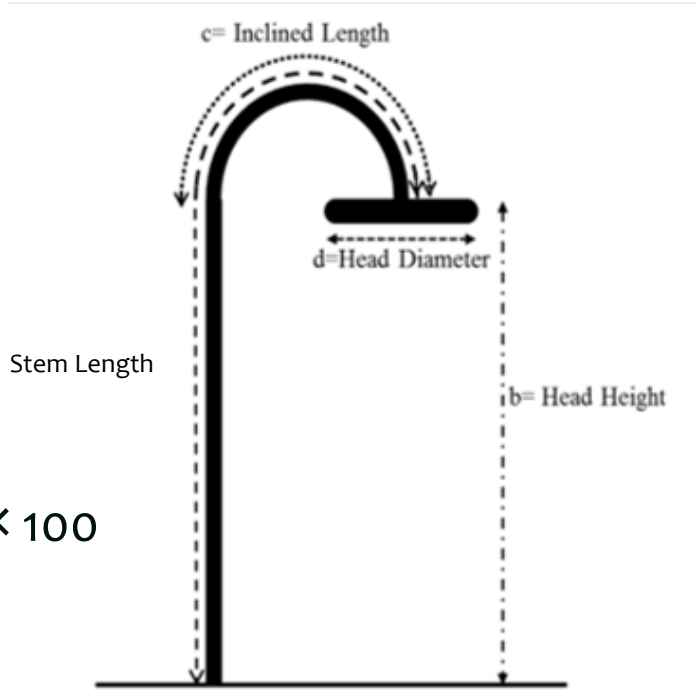
Data Collection

At peak maturity (1 plant per plot)



Inclined Length Method

- Previous research (Zakeri Haddadan et al., 2019)
  - Total length of inclined stem

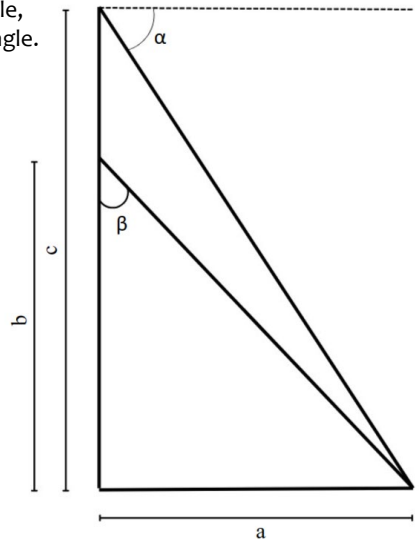


$$\text{Inclined Length} = \frac{\text{Stem Length} - \text{Head Height}}{\text{Stem Length}} \times 100$$

Trigonometry Approach

- Using triangles and angle and height measurements, converted angle from digital protractor to an actual angle

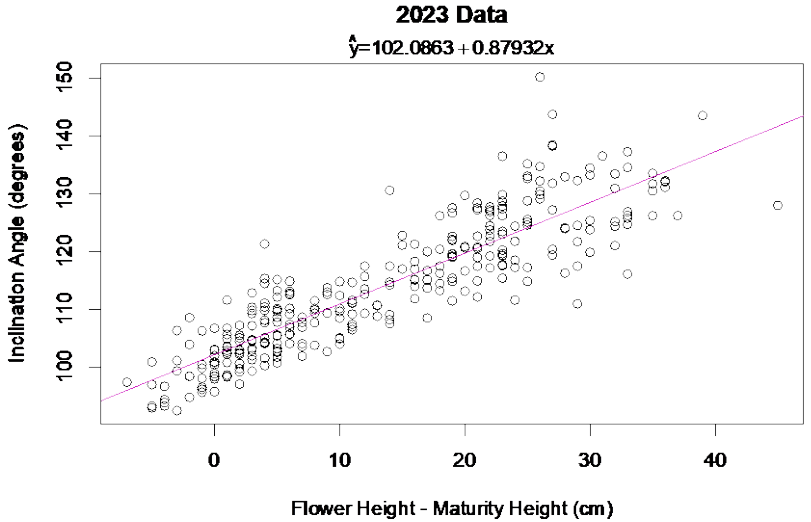
a = horizontal distance between stem and head,
b = maturity height minus head height,
c = vertical distance between mechanism and head,
α = maturity angle,
β = calculated angle.



$$180 - \left[tan^{-1} \left(\frac{\left(\frac{(213 - head\ height)}{tan(digital\ protractor\ angle)} \right)}{(maturity\ height - head\ height)} \right) \right]$$

Calculating Angle by Linear Model

- **R-squared = 0.78**
  - 2023 data best fit equation, trained 2022 data based on this
- Regression line allows calculation of inclination angle based on height difference



Broad Sense Heritability

	Flower Height	Maturity Height	Height Difference	Incline Length	Trig Angle
2022	0.81	0.82	0.73	0.76	0.58
2023	0.81	0.80	0.75	0.76	0.75
Across Years	0.71	0.61	0.61	0.54	0.53

Lower heritability across years due to GxE effects

Broad Sense Heritability

	Flower Height	Maturity Height	Height Difference	Incline Length	Trig Angle
2022	0.81	0.82	0.73	0.76	0.58
2023	0.81	0.80	0.75	0.76	0.75
Across Years	0.71	0.61	0.61	0.54	0.53

Lower heritability on 2022 trig angle due to learning curve on data collection

Correlation

	Flower Height	Maturity Height	Height Difference	Incline Length	Trig Angle
Flower Height	1.0	0.87	0.25	0.04	0.16
Maturity Height		1.0	-0.27	-0.44	-0.26
Height Difference			1.0	0.94	0.80
Incline Length				1.0	0.84
Trig Angle					1.0

Height difference and trig angle are highly correlated, showing accuracy of the linear model in predicting angle

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Incline Length				1.0	0.84
Trig Angle					1.0

Incline length has similar correlation to height difference with trig angle, but is less heritable (0.54 vs 0.61), indicating a better estimate

Efficiency

	Flower Height	Maturity Height	Stem Length	Head Height	Incline Length	Trig Angle	Height Difference
Average Time	35.85	34.43	33.09	32.61	65.70	122.03	70.28

Individual height measurements took similar amounts of time on average. The incline length method and height difference method were the most efficient, however height difference is more accurate overall

Summary

- Heritability and correlations of the linear model indicate we have created an improved method for estimating sunflower head inclination

Inclination angle = 102.0863 + 0.87932 x height difference

Next Steps

- Results open the opportunity to include this trait in quantitative analyses
  - Genomic selection
- Apply method to data obtained by drones or robots
  - Fully automate process

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ORIGINAL ARTICLE

Precision, quantitative measurement of sunflower capitulum inclination: A trigonometry-based approach

Emily M. DeValk[1] | **Brady D. Koehler**[2] | **Brent S. Hulke**[2]

[1]Department of Plant Sciences, North Dakota State University, Fargo, North Dakota, USA

[2]Sunflower Improvement Research Unit, Edward T. Schafer Agricultural Research Center, USDA-Agricultural Research Service, Fargo, North Dakota, USA

Correspondence
Brent S. Hulke, Sunflower Improvement Research Unit, Edward T. Schafer Agricultural Research Center, USDA-Agricultural Research Service, Fargo, ND 58102, USA. Email: brent.hulke@usda.gov

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Abstract

Sunflower (*Helianthus annuus*) is a widely cultivated crop that exhibits a trait known as capitulum (or head) inclination at maturity. This trait is influenced by various structural factors, including head weight, stem traits, and plant height. A sunflower head should be at an angle at which the head faces the ground to avoid damage from the sun and birds. While this desired inclination range is known, current methods, including visual estimation and a model of measuring inclined length of the stem, fail to provide precise measurements of angle. This study introduces novel approaches to mathematically measure the head inclination angle. The research, which was conducted over the 2022 and 2023 growing seasons, involved an aluminum rod equipped with a ruler and a digital protractor to measure various height and angle components. Using the data collected, three methods were applied for measuring inclination: a previously published model as a control, a trigonometry-based approach using angle and height measurements, and other model-based approaches. A linear model resulted in a formula to calculate the head angle of any plant based solely on two height measurements, the highest point of the plant at both bloom (R5) and maturity (R9). Calculations of heritability and correlation suggest this method has created a precise alternative to existing estimation methods. The resulting formula has the potential to be paired with measurements from high-throughput phenotyping methods, such as those facilitated with drones and ground robots, to fully automate the process of collecting head inclination data.

THANK YOU

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National Sunflower Association

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