An introduction to scientific investigations for SBA Biology

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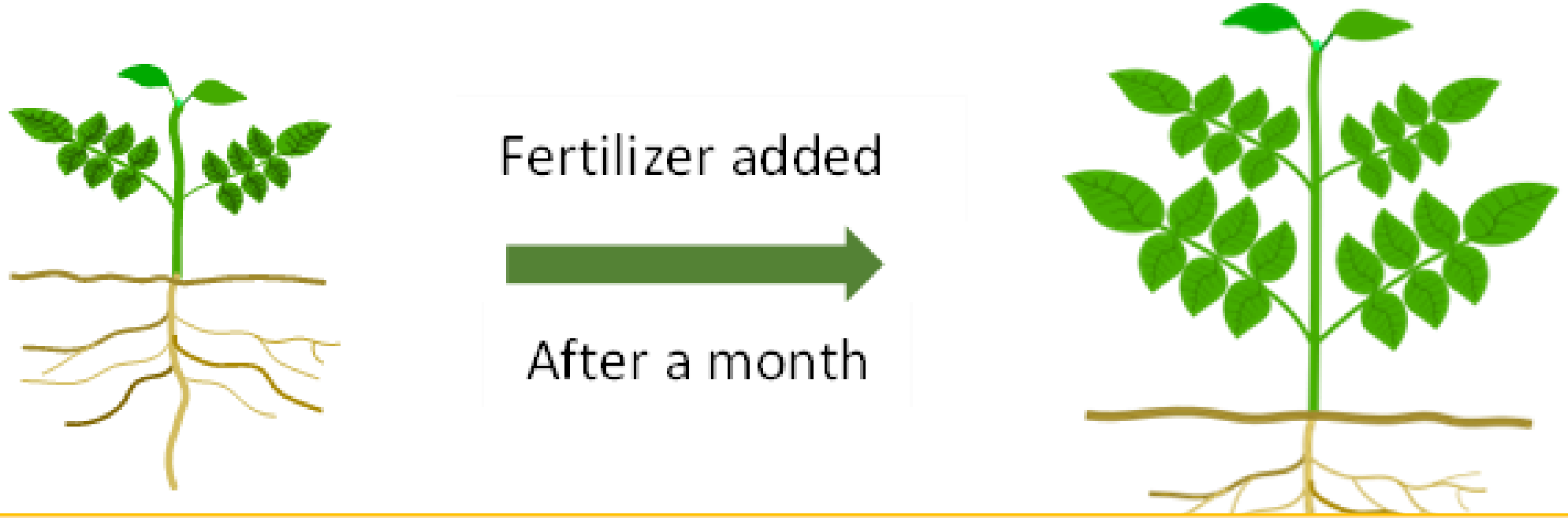
Does the addition of fertilizer into soil promote the growth of plants?

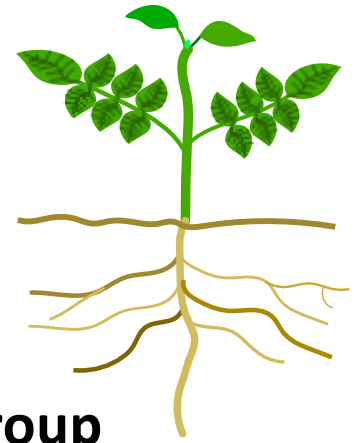


Critical thinking

The plant will grow even without the addition of fertilizer. How can you be sure the growth of the plant is caused by the addition of the fertilizer?

(A) A controlled experiment

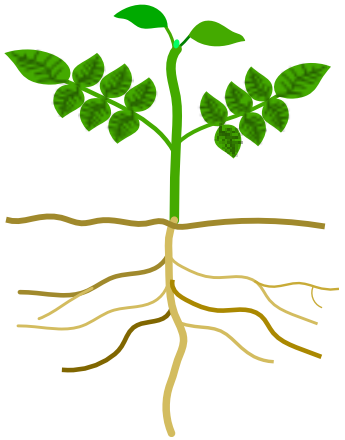
Treatment group



Fertilizer added

After a month

Control group



No fertilizer added

After a month

Results

The plant added with fertilizer grows much larger than the plant without fertilizer added.

Critical thinking

The plant in the control group may grow slower due to poorer soil, less water, less sunlight, etc. How can you be sure that it is caused by the lack of fertilizer?

Variables

	Treatment group	Control group
Independent variable (change intentionally)	Fertilizer added	No fertilizer added
Dependent variable (the results to look at)	Growth	Growth
Control variables (keep the same between groups)	Types and size of the plants, soil nutrients, soil water, sunlight, etc.	

Why does the soil of the two groups need to be the same?

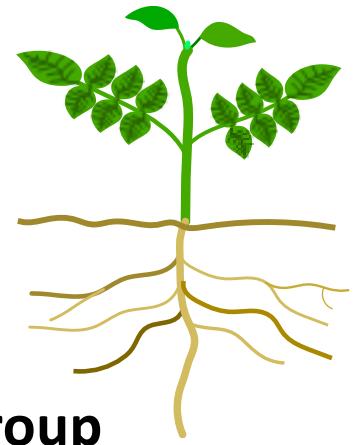
The soil will affect plant growth. If soil conditions are different, we do not know the difference in growth between the two groups is caused by the soil or the fertilizer.

(A) A controlled experiment

Critical thinking

What if the plant in control group happens to grow slower as a natural variation?

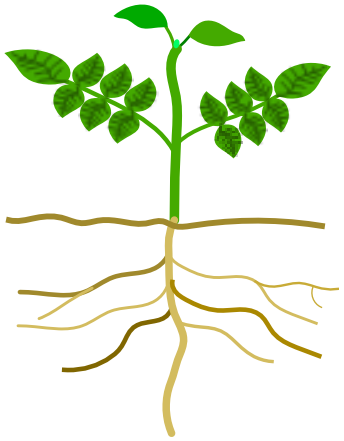
Treatment group



Fertilizer added

After a month

Control group



No fertilizer added

After a month

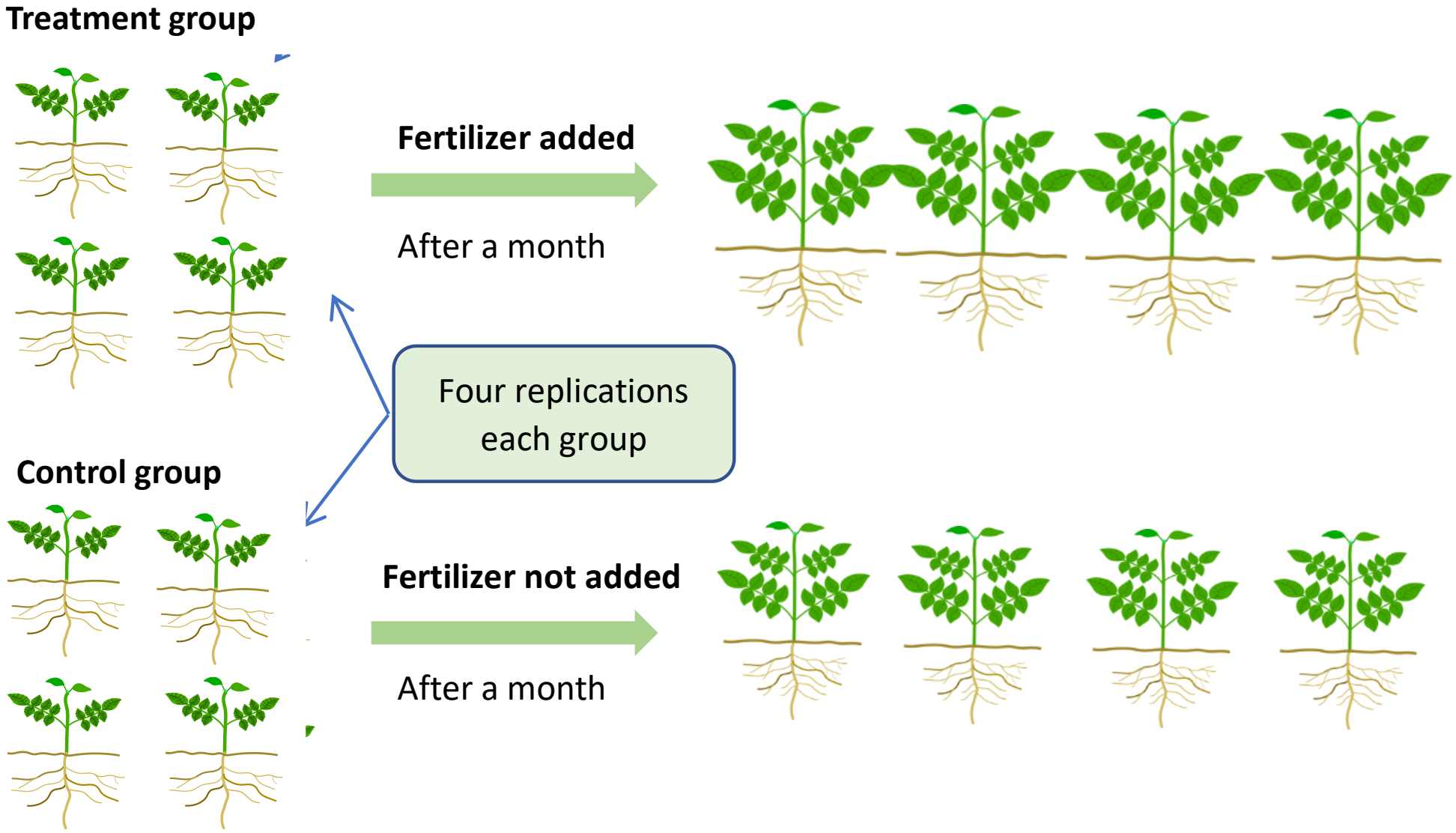
Results

The plant added with fertilizer grows much larger than the plant without fertilizer added.

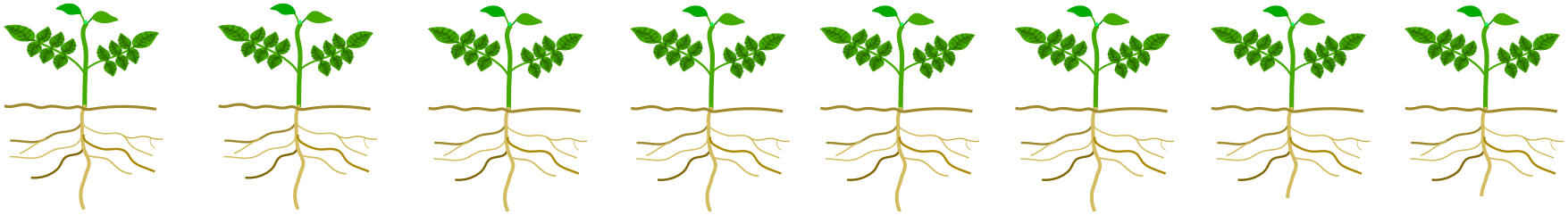
Between subject study – problem of individual variation

Within subject study – problems of carryover effect that creates many uncontrolled variables

A controlled, replicated experiment

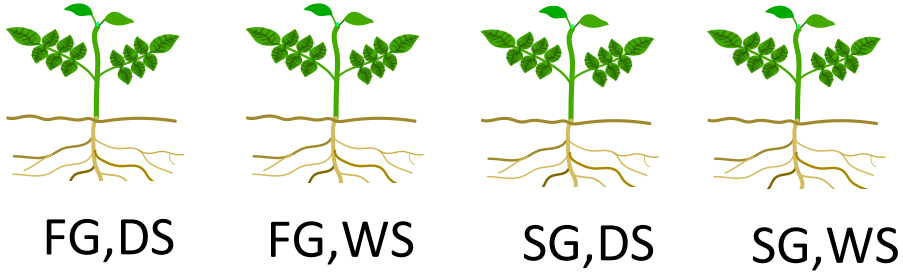


With enough replications and random allocation, the ‘averages’ of the plants and the conditions between the two groups would have no big differences.

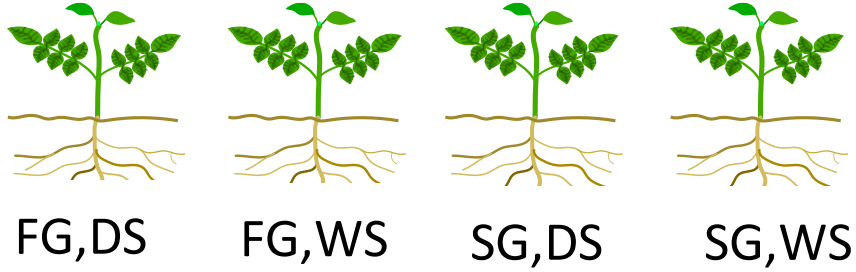


FG - faster growth
SG - slower growth
DS - drier soil
WS - wetter soil

Random allocation into two groups

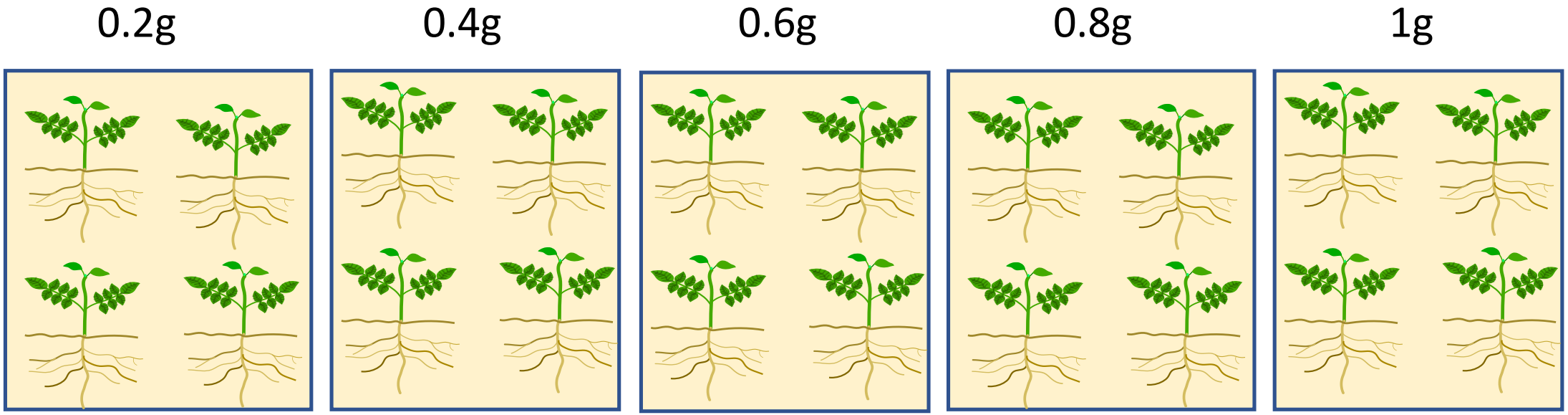


Treatment group



Control group

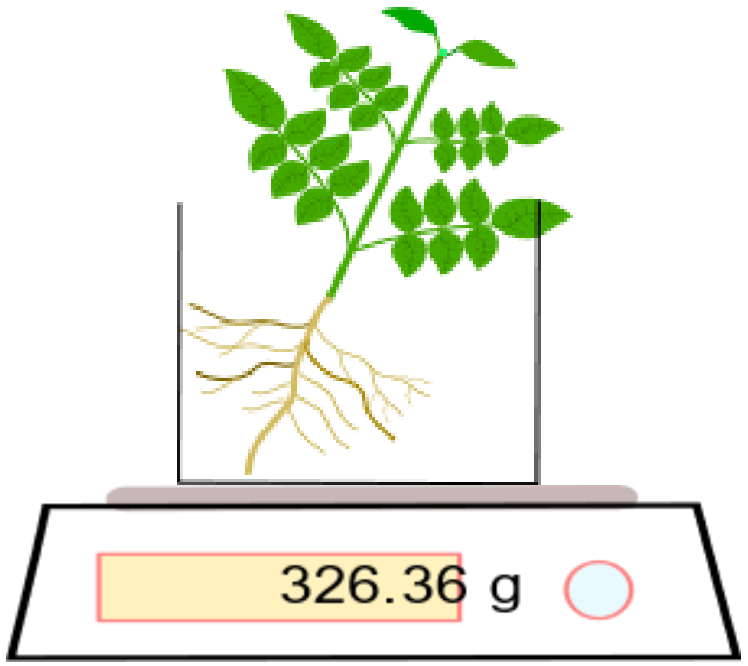
Another design with quantitative IV and DV



This design can answer one more question:

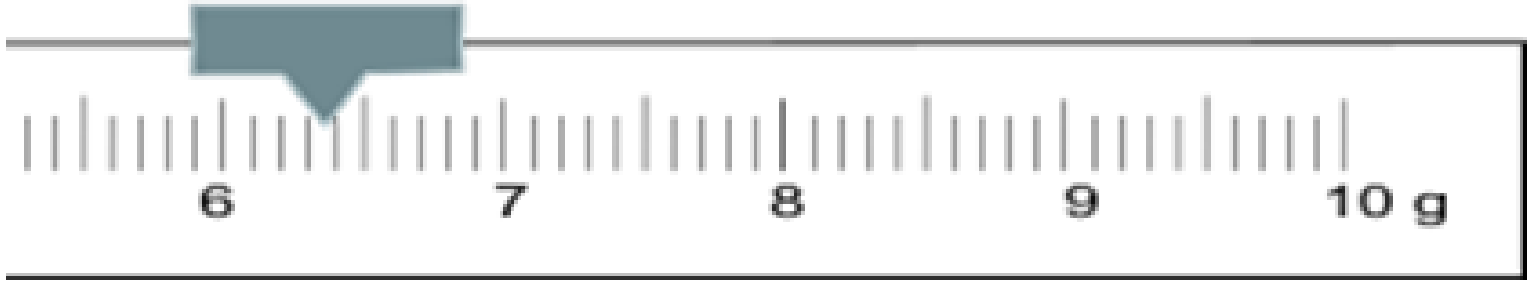
How much fertilizer should be added into soil to produce the best plant growth?

Measurement



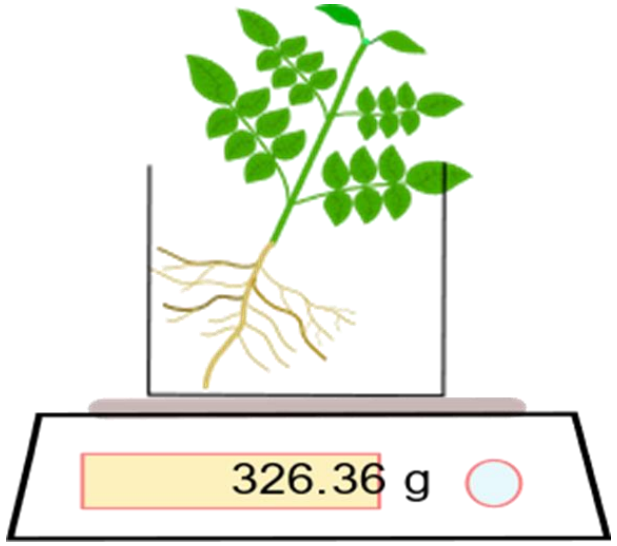
Measure the mass of a plant

- Do you choose the right instrument – accuracy and range?
- Do you use it correctly?
- Do you repeat the measurement to check and reduce random errors - precision
- Do you use another balance to cross check the data and reduce systematic error/biases - accuracy



Accuracy and precision fit for purpose – no need to be as high as possible!

DV → Measurement



Growth of plants as measured by:

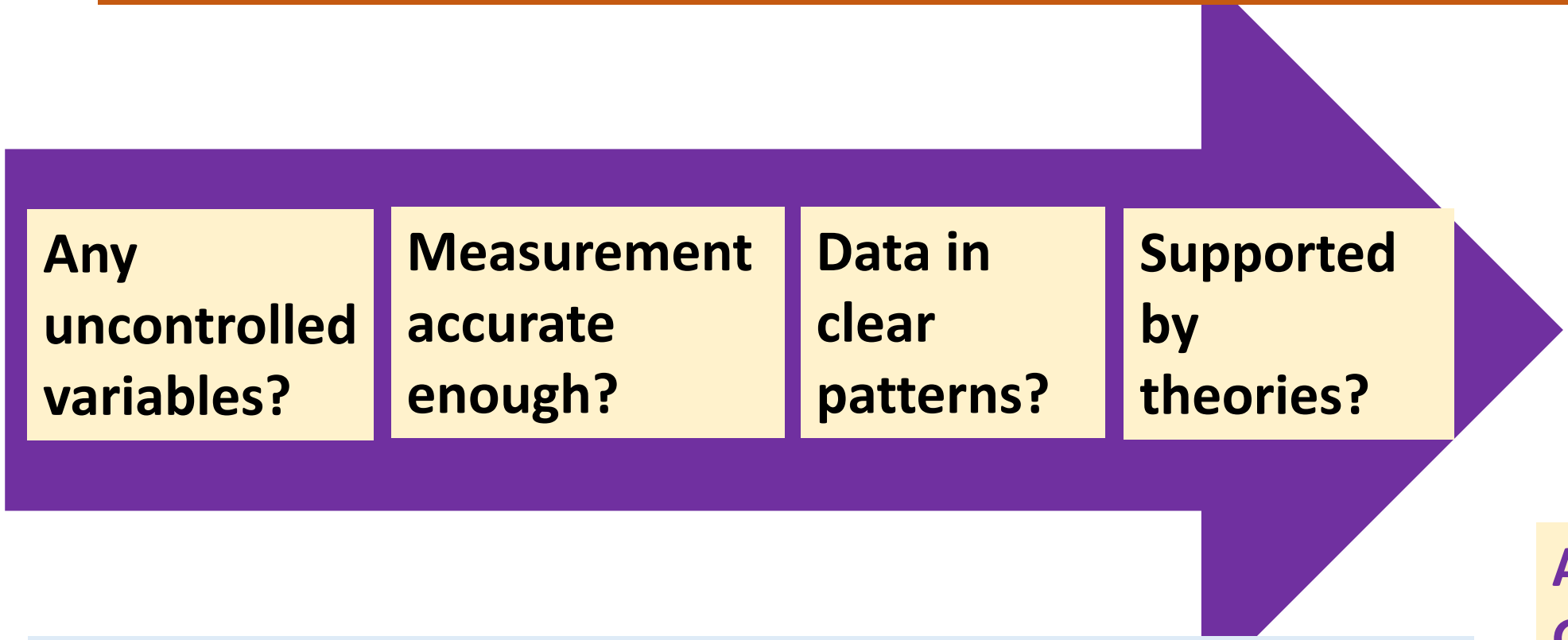
- Wet mass vs Dry mass
- Whole plants vs shoot/root
- Number of leaves
- Height

What is the best measurement of plant growth and the practical limitations?

These discussions are sometimes more important than the little measurement errors that would not affect the conclusion.

Discussions and conclusions

The core of scientific reasoning: draw an evidence-based conclusion



Conclusions

Assumptions
Generalizability

- Do not repeat those points in the Design
- Base the discussions on the data and the processes of doing the experiment

Discussions and conclusions

	Fertilizer added (n=4)	No fertilizer added (n=4)
Change in average dry mass (g)	+45.8 (42-52)	+23.2 (19-26)

Is the difference between groups real (compared to the within group variation)?

Is the measurements accurate enough? Any repeated measurement showing the random errors?

Any uncontrolled variables identified e.g. the plants in the control group got less sunlight, more pests, or poorer soil?

Hypothesis

A possible answer/explanation to the investigative question?

Question

Do fertilizers promote plant growth?

Hypothesis (or prediction?)

Fertilizers can promote plant growth.

Experiment

Test the hypothesis directly.

Question

Why do fertilizers affect plant growth?

Hypothesis (possible explanation)

The nitrogen in fertilizers allows the plant to make more chlorophyll for photosynthesis.

Prediction (derived from the hypothesis)

Plants supplied with a nitrogen fertilizer will have more chlorophyll.

Experiment

Test the prediction (not the hypothesis).

Some important points

- Have students explain rather than describe their designs
- Have students work on more complex data (quantitative, multiple IV, DV, repeated measures, replications)
- Have students assess the credibility of the data and integrate it with the limitations of the conclusions.