Project Summary of Methods and Results & Design Notebook

1. Design Brief: Project and Client Background and Statement

The precision planter was born out of an International Development Design Summit in 2015 hosted by the International Development Innovation Network, where the tool was spearheaded by Mathambo Ngakaeja, a farmer in D'kar, a rural community of Botswana. The purpose of the tool is to be able to plant appropriate amounts of seed and fertilizer into the soil without ploughing in order to improve soil fertility and crop yield. The main end goal for this project is to implement this tool in farms across D'kar and surrounding regions, in order to establish and improve farmer livelihood, self-sufficiency, and environmental sustainability.

Many parts of the project had not been attended to during the summit. In D-lab II, we attempt to build and improve the dispensing and dispersal mechanism under the prototyping process of D-lab II. In August, the prototype will be built and tested in Botswana, and revised as needed.

2. Design Process and Methodology: Criteria and metrics

Criteria	**Qualitative/ Quantitative**	**Testing Procedure**	**Target Value (units)**	**Metric (units of measurement)**
All materials sourced locally	Quantitative	Count the materials	100%	# of materials sourced locally / total number of materials * 100%
Weight	Quantitative	Scale	4	lbs.
Weight	Qualitative	Focus group reporting on ability to pick it up with ease after using it 100 times	>4/5	People say it's "light enough"
Soil clogging tip	Quantitative	Jab planter into ground 100 times to a depth of 6in and dispense seed	<5/100	# of times it clogs
Ease of puncturing soil	Qualitative	Focus group reporting on ability to jab planter into soil,	<5/100	# of times user had difficulty jabbing into soil
User strain	Qualitative	Focus group reporting on ability to use with ease after using it 100 times	>18/20	People say it does not strain their body

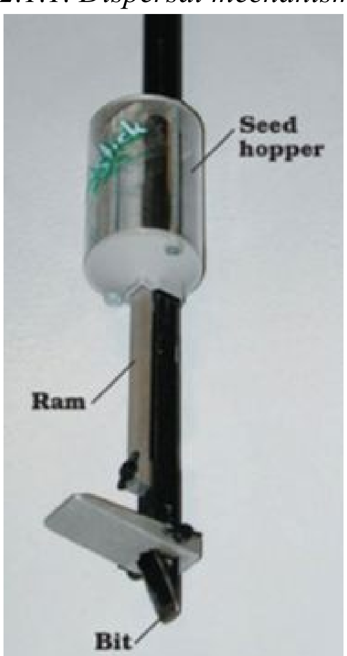
Speed	Quantitative	Focus group performing 20 jabs, average the amount of time it takes per jab/dispense	<5 sec.	Seconds
Planting accuracy	Qualitative	100 jabs into the soil; ensure that the seed/fertilizer plant within 10% of where the farmer jabs into the soil	<5/100	# of times user plants outside of 10% range
Appropriate seed allocation	Quantitative	Jab planter into ground 100 times, dispense seed and fertilizer, and measure dispersed amounts	<5/100	# of times it does not dispense appropriate amounts
Appropriate depth	Quantitative	Jab planter into ground 100 times, dispense seed and fertilizer, measure depth it was found in soil	<5/100	# of times it does not at dispense appropriate depths
Simplicity of build and functionality	Qualitative	Focus group learning how to build and use tool, specifically using the seed dispensing mechanism and jabbing	20/20	People say it's easy to build and use
Smooth operation	Qualitative	Planter movement and mechanism are smooth; doesn't stick	< 5/100	# of times the tool sticks

*Elaborations of criteria found in Appendix.

This is the original prototype built by the farmer. The two main focuses are redesigning the dispensing mechanism at the top of the tool with hoppers, which releases appropriate amounts of seed and fertilizer, and the second mechanism is the dispersal mechanism located at the bottom of the tool, which releases the seed and fertilizer into the soil.

2.1. Prior Art

2.1.1. Dispersal mechanism



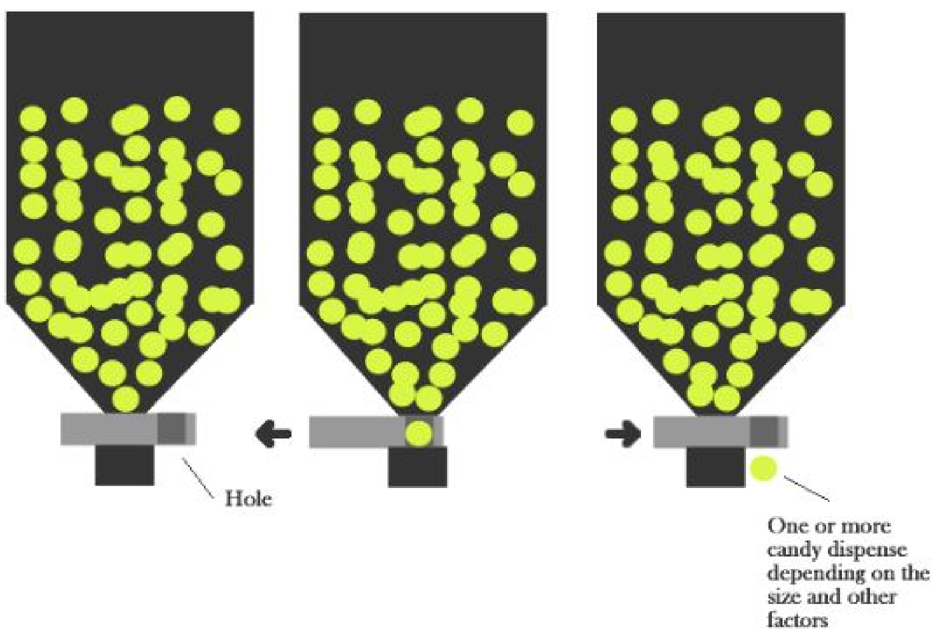
Seed Stick source: Oklahoma State University

Through our search of pre-existing designs, we came across the seed stick. As the bit is jammed into the ground, it picks up seed from the hopper and drops it into the center tubing. When the bit is pulled up, it provides enough clearance for the seed to fall in front of the seed pusher. As the bit is pushed into the ground again, the seed pusher pushes out the seed. We like this design because it is simple and it clears the tip of any soil every time it pushes the seed out.

The original tip design has a flap door that opens outward. We believe that this will fail once it is jabbed into the soil because there is no clearance for the door to open. We like the seed stick tip because it does not require as much clearance as the original design when opening up. Additionally, it clears the tip every time it dispenses seed and fertilizer. Therefore, our dispersal mechanism is based off of this design.

2.1.2. Dispensing mechanism
We will begin this process during the summer. We have reviewed a few mechanisms that we are interested in building.

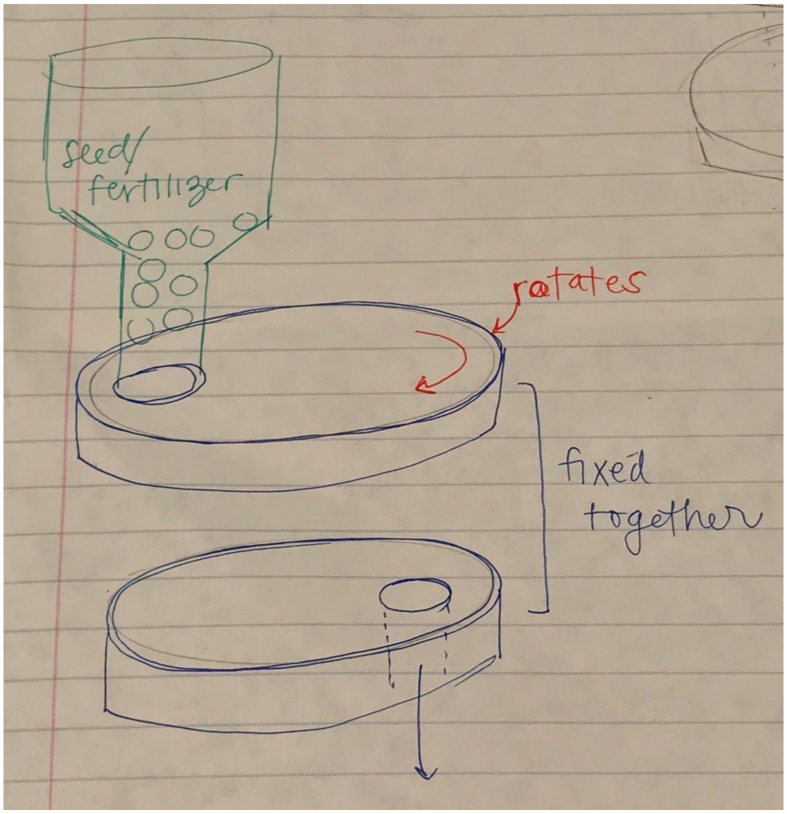
2.1.2.1. Design 1



Source: Nascimento, Diego. “Robotic part to dispense candy.”

We like this design because it is simple. Essentially, there is a rod containing a hole that moves left and right. When the hole is adjusted to align with the hopper, seed/fertilizer dispenses into the hopper. It stays in this hole until it is further pushed to the original position, where seed/fertilizer is released. However, we are unsure whether this design is appropriate for the types of seed and fertilizer that will be used. This design will be particularly difficult if the fertilizer is a powder.

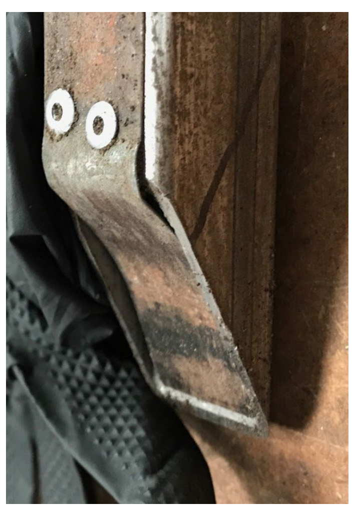
2.1.2.2. Design 2



Similarly to the first one, it includes a hole large enough to hold a desired amount of seed or fertilizer. This hole is located on a plate. As the plate rotates, when it aligns with the hopper, a certain amount of seed/fertilizer will fall through the hole. As it continues to rotate, once it aligns with the plate below, the seed/fertilizer will fall through. Again, limitations on this design may be the size of seed/fertilizer. There is a possibility of having interchangeable sizes to allow for a variety of seed sizes.

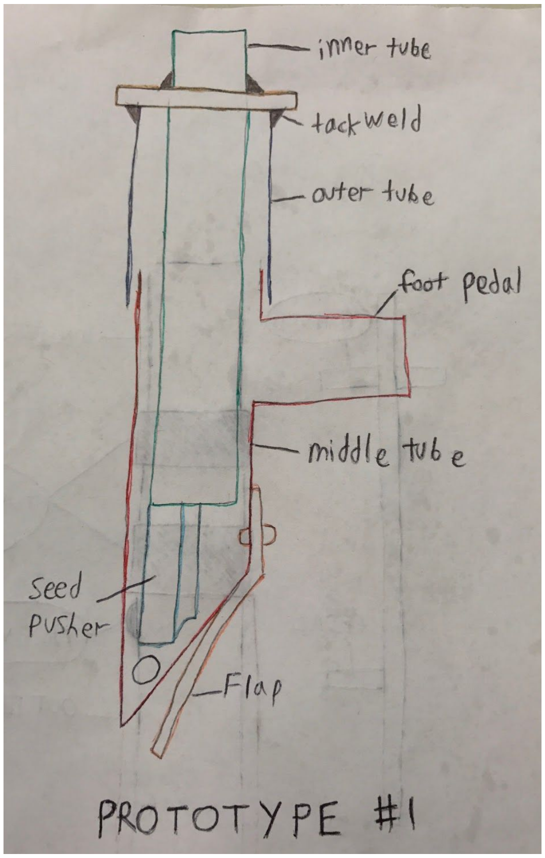
3. Results and Discussion

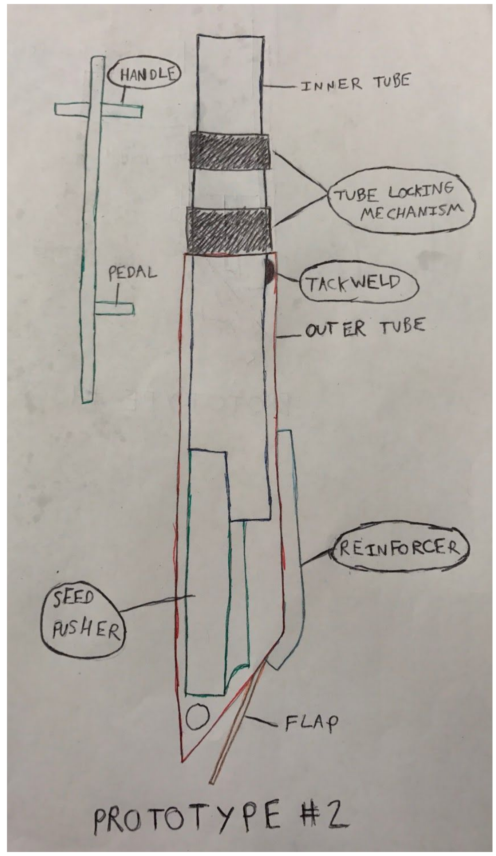
Before



After

3.1. Prototypes and Testing





The initial prototype, as seen in the picture above, performed a variety of tests to determine effectiveness of seed dispensing mechanism that was the focus of the design thus far. The sample under study was the bean, chosen due to being the largest possible seed size used by the precision planter. This would determine whether the precision planter would get clogged or not. Tests areas included no soil, tilled soil, and untilled soil at the Student Farm. Success is defined as the seed dispenses into the soil, unbroken at a proper depth. Failure is defined as the seed getting stuck in the planter, or breaking apart into bits and pieces as it is dispensed into the soil. The results are as follows:

Seed type: bean				
Soil Type	No soil (air)	Tilled soil	Untilled soil	Untilled soil (with new procedure)
Success	10	10	5	10
Failure	0	0	5	0

Our results show that issues do not occur until we test in untilled soil, which is the aim for this tool. We realized that as the tip is jammed up against the soil, when the seed pusher tries to push it out, it crushes the seed because there is no room for the seed to dispense.

Through the realization of a specific operating procedure, the planter is able to dispense the seeds with utilization of the mechanism. The technique requires the user to jab the planter into the soil; when the tip is into the soil, the user presses the planter until the user feels like he/she can't push anymore. Then the final step requires an upward movement by the user to create clearance for the seed to dispense as the pushes it out. This technique was carried over to the 2nd prototype.

The building of the 2nd prototype resulted in many new aspects to the design that are more than likely to be carried out in the final design. These additions included reducing the needed number of pipes for the body from three to two. This not only makes the planter lighter, but also cuts down on materials used and building time. This was the result of creating a new locking mechanism to limit the movement of the pipe pieces. This involves two same sized pipes that prevent the planter from condensing too far, while a tack weld on the inside of the planter prevents it from being extended too far. In addition, the flap was widened to rest on the steel tip edges for support, and was connected to a reinforcer to prevent the flap from bending repeatedly and thus grow weak. The seed pusher was doubled in thickness, which helps to prevent twisting of the pipes.

One issue we run into is the "stickiness" of the tool. This occurs when the inner seed pusher rubs against the outer tube. We realized through our work that having too much clearance between the tubing gives it clearance to twist, making it stick even more. Therefore, in future prototypes, we will be more aware of this issue as we build or even address it through a new design in our next prototype. We may use a plastic seed pusher to limit this effect in future designs.

3.2. Meeting Criteria

All of the materials used in the shop were made of steel, either circular or square tubing, which will not be hard to find in Botswana. Our tool addresses the concern of soil clogging by how the seed pusher's sliding movement clears the tip. We cut the tip to have an angle, for ease of puncturing the soil. When planting up to 3in, it does not seem to be an issue. Any deeper may present difficulties. Our simplifications in the number of tubing required in our second prototype aim to address the criteria of simplicity.

Additionally, the weight of the tool does not seem to be an issue; however, a gap in our project is feedback from farmer groups on the weight and overall ergonomics of the tool. Further tests need to be performed to understand its speed, and overall allocation and depth accuracies. We are continuing to improve the prototype to ensure that it does not stick.

4. Conclusion

Conclusions from the field tests were that the seed pusher caused too much variability in expelling the seed and a defined procedure is needed for use. At the same time, the specific procedure that was developed poses a problem for implementation. The planter demands a simplistic operation to help with streamlined education. We have concluded that we must directly tackle the problem of dispensing in untilled soil while keeping the operation of the planter simple. At this moment the dispenser works but the planter will need to be constructed under a specific order of steps in order to have the most streamlined movement of the pipes. Through designing so far, we have followed the design of the seed stick closely, but have not been able to successfully create its usability in hard untilled soil.

5. Recommendations: Specific Next Steps

The next steps for the project will consider feedback from the final presentation evaluators and our own discoveries during design and building.

1. Test the prototype 2. This will be a thorough expansion of tests performed with prototype 1. It will include an evaluation of successful seed dispensing. The variables for the test will include different soil types. The mechanism will be tested in the air (no soil), under tilled soil and untilled soil at the student farm. All seed types provided by our client will be tested: melon, corn, sorghum, sweet reed and bean. Each seed will be placed in the mechanism and dispensed for each soil type. Reasons for failure will be noted and used for future design adjustments.

2. Establish proper placement for foot pedal. Considerations into the average height of farmers in Botswana will be integral to deciding where the foot pedal should be to maximize comfort.

3. Develop new technology to help dispense seed in untilled soil. This will involve more thorough technological research of current benchmarks. The desire is to have a simply built component of the piercer that does not create complex operation for the planter, yet allows for flap opening amid dirt. This would take form in a strong dirt-pushing capability, or a operation to automatically remove the planter from the dirt to dispense.

4. Develop the allocation mechanism. This will involve combining a potential designs mentioned above with client specifications. This process will involve designing and building the specific mechanism for implementation on the current prototype. Testing will then be performed to ensure accuracy of seed and fertilizer allocation for dispensing.

5. Create a schematic and design specifications. We will need to create a budget for each precision planter, and make a list of all materials needed in construction. This will be cross-referenced with materials locally available in Botswana to ensure economic and technological sustainability of the planter.

6. Reconsiderations into planting seed and fertilizer together. Further research needs to be made into understanding the complexities of planting seed and fertilizer together. Mir Shafii from the Western Center for Agricultural Equipment has expressed concern over the possibility that the fertilizer could burn the seed when they’re in contact.

7. Ensure the hole made for seed is covered after planting. So far, our tests show that this is not an issue with soils at the Student Farm.

8. Add an adjustable plane to the base of the planter. This will allow proper insertion depth of the planter in soil for the specific crop type. This will limit how far the seed is dispensed into the soil.

9. Redesign planter operating procedure. Change the 4 step method of seed insertion into a smooth simple motion to reduce user strain and promote usability.

Bibliography

Nascimento, Diego. "Robotic part to dispense candy." *Stack Exchange*, https://robotics.stackexchange.com/questions/2411/robotic-part-to-dispense-candy.

Oklahoma State University. "OSU Hand Planter for the Developing Country." *Oklahoma State*, http://www.nue.okstate.edu/Hand_Planter/Hand_PlanterPictures.htm.

Appendix: Design Notebook Documents

Criteria Elaboration

2. Criteria and metrics

We want the tool to replicable and operable by any farmer. The following criteria were developed out of the goal to create an ergonomic tool.

2.1. Materials sourced locally

The goal is for 100% of the materials used to be easily sourced in Botswana.

2.2. Weight

A decent weight will help ensure that the tool can be used with ease without straining the user, measured in pounds.

2.3. Tip does not clog

This ensures that the seed and fertilizer are not blocked from dispensing, which is measured by the number of times it clogs.

2.4. Ease of puncturing soil

The ease of puncturing into the soil eliminates possible user strain and lowers labor intensity, which will be measured by counting the number of times the user has struggles with puncturing after a prolonged amount of time in varied soil areas.

2.5. Speed

The tool should plant seed and fertilizer at a fairly fast pace, measured in the time (seconds) it takes to plant seeds and fertilizer.

2.6. Planting accuracy

The tool needs to plant within 10% of the seed growth area, measured in inches across the surface of the soil.

2.7. Appropriate seed allocation

The tool should plant the correct amount of seed and fertilizer, as determined by the user. This will be evaluated by counting/measuring the amount dispensed and comparing it to amount suggested by the agriculture industry.

2.8. Appropriate seed depth
The tool should plant seeds/fertilizer at the correct depth according to crop type. This will be evaluated by measuring the depth the seed/fertilizer is planted in the soil.

2.9. Simplicity of build and functionality
The tool should be built in the simplest way possible so farmers can easily build it themselves and fix it if necessary.

2.10. Smooth operation
The tool should operate smoothly, without locking of the pipes, for 95% of trials.