Seed Planting Assistive Device Entourage (SPADE) (Duke University)

by Resna1215sdc on MAY 5, 2012 in UNCATEGORIZED {EDIT}

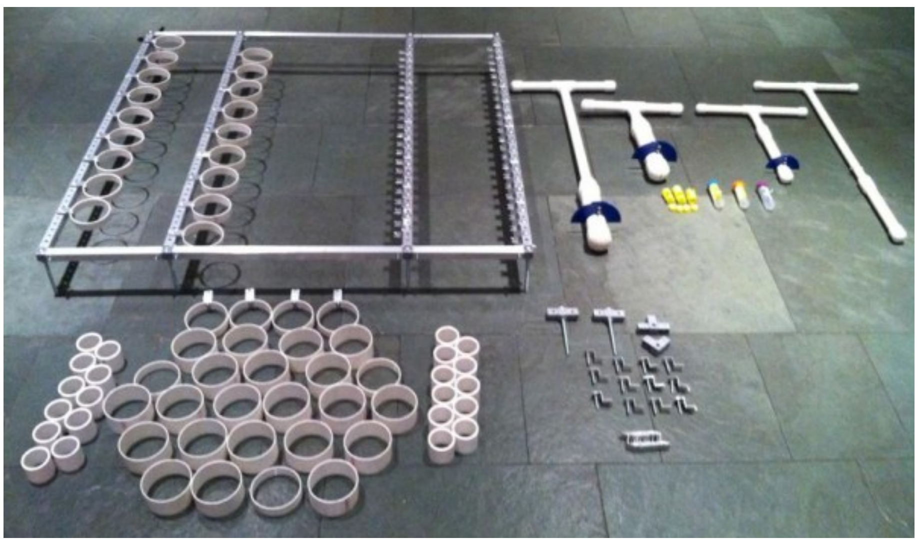

Figure 1: Completed Devices in Their Entirety

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ABSTRACT

Volunteers with disabilities at the Goodwill Industries of Eastern North Carolina Nature Center experience difficulties with hole spacing, hole digging, and delicate seeding functions while planting seeds and plugs in the garden. The goal of this project is to design devices that resolve challenges in independent and accurate planting, while still preserving opportunities for close interactions with nature. The solutions include 1) a spacing device for hole alignment and positioning, 2) a digging device for creating planting-holes at variable depths and sizes, and 3) a seeding device for dispensing 1-3 seeds at a time. Ultimately, this system helps volunteers perform their tasks with higher accuracy, greater independence, and a stronger sense of accomplishment.

BACKGROUND

Goodwill Industries of Eastern North Carolina (GIENC) is a non-profit organization that helps people gain job skills by providing educational and life-enriching activities. In the GIENC Nature Center Program, adult participants with varying cognitive and/or physical disabilities engage in horticulture to grow vegetables donated to the Eastern North Carolina Food Bank. Most of the volunteers have had traumatic brain injuries (TBI) that cause long-lasting physical, cognitive, social, emotional, and behavioral effects (1).

The volunteers in the Nature Center Program tend to have limitations associated with coordination, memory and concentration. Because planting tasks often require high levels of dexterity and coordination, many volunteers experience difficulties with various planting operations, resulting in diminished independence, reduced motivation, and lower productivity. The main planting challenges outlined by the staff include spacing seeds and plants in a straight line at even intervals, digging holes with desired diameter and depth, and handling small seeds with 1-3 seed resolution. Without substantial help from staff, the planting often appears jagged and clustered, requiring time consuming and wasteful weeding.

PROBLEM STATEMENT

The goal of this project is to help volunteers with disabilities gain independence in their planting therapy program, in addition to planting seeds more easily and efficiently.

RATIONALE

Although commercial row-seeding devices are available (2), the majority of such devices are complex and bulky. Persons with cognitive or physical disabilities may encounter difficulties with these devices due to distracting functionalities, complex operations, and electrical safety concerns, all of which require additional supervision and further deny volunteers independence.

The three constructed devices allow precise spacing, digging, and seeding. When using the devices, the volunteers perform tasks with more accuracy, ultimately resulting in increased independence, motivation, and demonstrated productivity. Unlike many automatic all-in-one commercial products, these devices preserve therapeutic hands-on interaction with the earth.

DESIGN AND DEVELOPMENT

After consulting with the clients, we identified and characterized three key aspects that needed to be addressed. First, the volunteers had difficulties making straight and even holes at different intervals on both the raised beds and ground rows due to limited spatial perception. Next, they experienced difficulties in digging holes of proper diameter and depth for both seeds and plugs (i.e. small plants). Finally, it was frustrating and challenging for many to place 1-3 seeds per hole due to limitations in dexterity when working with small seeds of 2-5 mm in diameter. To address these needs we developed three separate devices, named the Spacer, Digger and Seeder, as described below. Although the devices were designed for our specific clients, they have broader appeal in the general field of gardening.

Spacer

To address the need for even and straight spacing of the holes, we designed a Spacer to mark hole positions on the ground. Due to the multitude of working environments, hole sizes, and seeding configurations, modularity was critical. The need for variable hole spacing was addressed by combining spacing rods, constructed using 1” square aluminum tubing with marker-placement holes spaced 1” apart, with a set of independent markers that attached to the rods at any necessary interval (Figure 2).

Figure 2: Spacer with rings

To accommodate work in 4×8' raised beds, the spacing rods can be connected in a four-lane parallel grid using connecting rods and L, T, and I connectors. The same connectors can be used to chain the four spacing rods in series to produce a 16-foot rod for use on long ground rows. Two types of markers, arrows and rings, are provided for locating seeds and plugs respectively. All connectors contain quick release pins for easy grid assembly, as well as anchoring bolts to secure the grid elements to the ground (Figure 3).

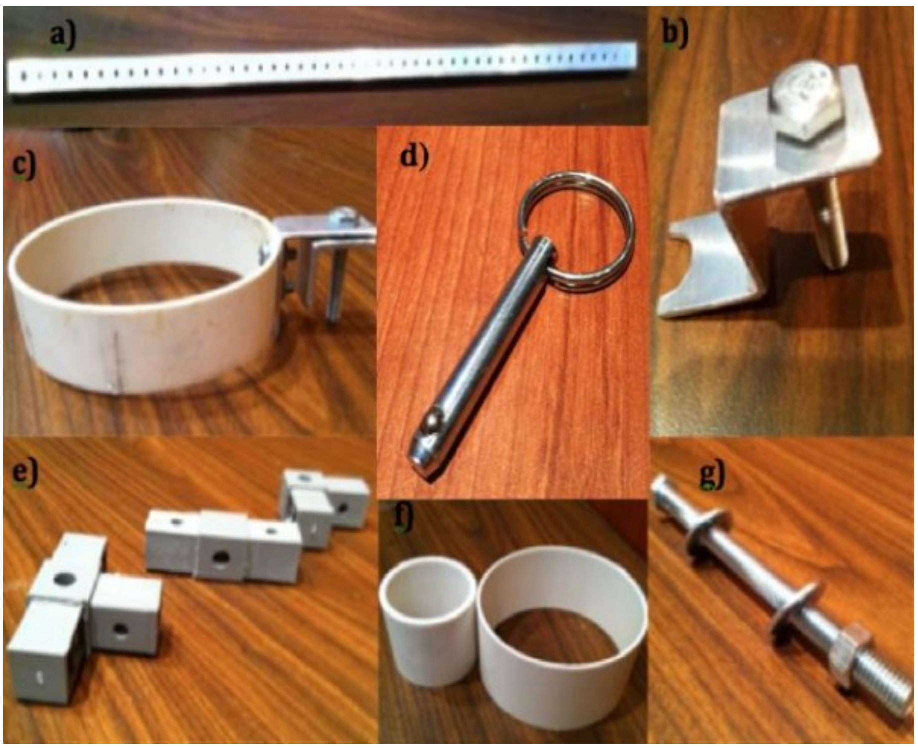

Figure 3:Various components of the Spacer

During testing, the ring markers were shown to be stable enough for independent use; therefore, two sets of 2" and 4" diameter stand-alone ring markers were provided for use in non-linear planting configurations. For robustness and durability, all components were made from aluminum, polyvinyl chloride (PVC), and DuPont Super Tough Nylon Resin. The mechanic drawings of the spacer components are shown in Figures 4a-c.

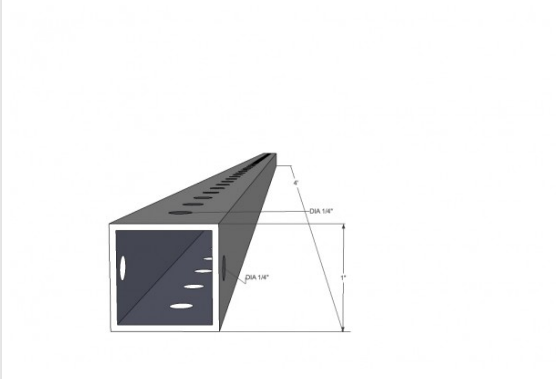

Figure 4a: Schematic Drawing of an aluminum connecting rod

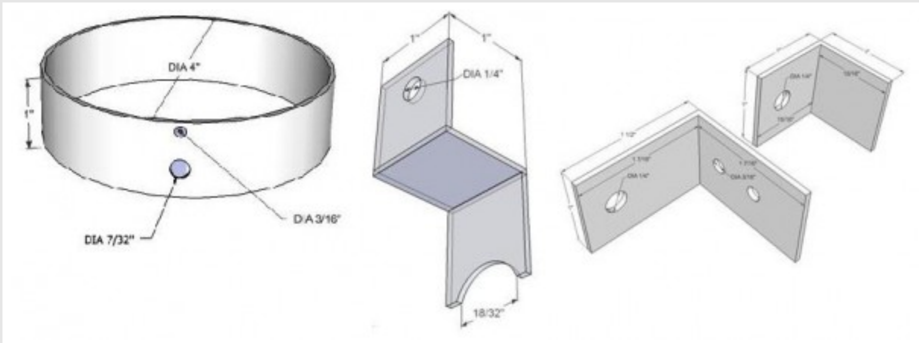

Figure 4b: The ring marker, the arrow marker and the L brackets

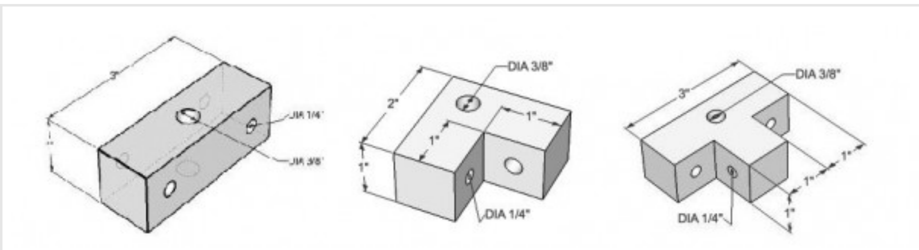

Figure 4c: L,T, and I Connectors

Digger

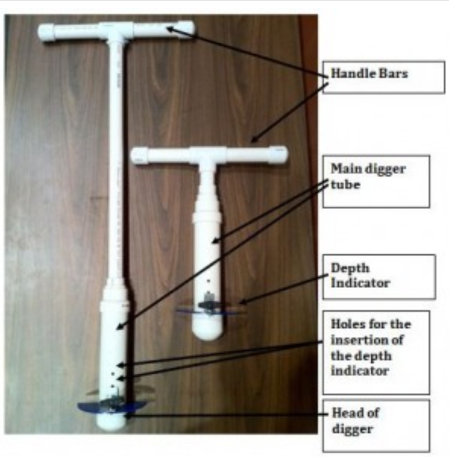

Figure 5: 2'' Diggers (left:ground beds; right:raised beds)

The Digger helps create a uniform hole both in diameter (1''-2'') and depth (2"-4"), using the principle of a garden "dibble", which simply displaces rather than removing dirt. Diggers of two different lengths are provided: a 3' tube length model for the ground beds, and an 18" model for the raised beds (Figure 5).

Three holes on the sides of each Digger allow insertion of a detachable depth indicator to create consistent holes 2, 3, or 4 inches deep. The handles allow the volunteers to have a firm grip on the Digger, while comfortably using their upper body strength to push it into the ground. To dig a hole with a specific depth, volunteers choose the Digger corresponding to the height of the planting bed, insert the depth indicator at desired height, and push the Digger into the ground at the marked area until the depth indicator contacts the surface (Figure 6). To create holes of different diameters, two pairs of Diggers are provided: two with a 2" diameter tip, and two with a 1" diameter tip. The schematic for the digger is shown in Figure 7.

Figure 6: The depth indicator in use.

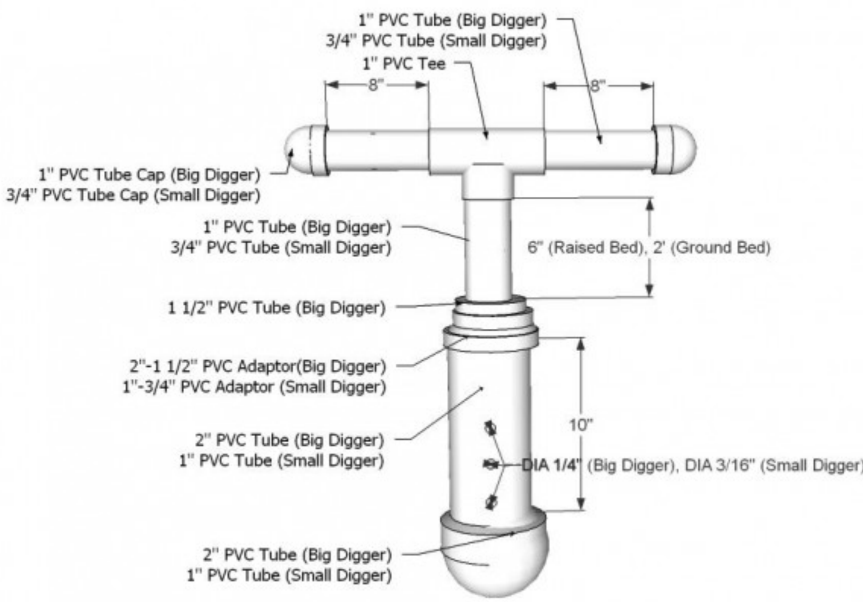

Figure 7: Schematic of the Digger

Seeder

The Seeder dispenses 1-3 seeds with each press of a lever. As depicted in Figure 9, when the lever is pressed and lowered the disk rotates (clockwise rotation), exposing a seed pocket to a top seed reservoir (black lines), and providing seeds to the pocket. After the compression, the lever is released, allowing the torsion spring to rotate the disk back to the original position, and the seed to fall due to gravity and inertia (counterclockwise and red arrow). The disk is housed within the cavity of a plastic cylinder for protection and rotational stability. Both the cylinder and disk were manufactured from ABS plastic using a 3D CAD printer, using design models created with SolidWorks. The disk and cylinder complex is housed in a

Figure 8: Different components of the Seeder

protective casing, modified from a BD Falcon 50mL conical tube, with a milled slot to accommodate lever movement. The tip of the conical tube is cut to allow seed exit (Figure 8).

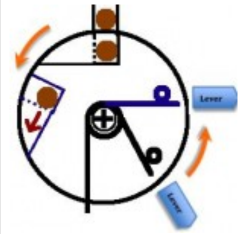

Figure 9: Mechanism of the Seeder

To accommodate seeds of two different sizes (e.g. larger beet seeds and smaller cabbage seeds), disks with different-sized reservoirs were manufactured and two different Seeders were provided to the clients.

The initial Seeder design required users to turn a T-shaped knob in order to dispense seeds. Because this mechanism required the use of both hands, we replaced it the lever-operated design. After client testing, we also replaced the extension spring on the outside of the external tube with an internal torsion spring. This substantially increased the safety and usability of the device (Figure 9). The schematic of the seeder is shown in Figure 10.

Finally, for storage and transportation, a golf bag and a 50 gallon container were provided to house and transport all planting device components.

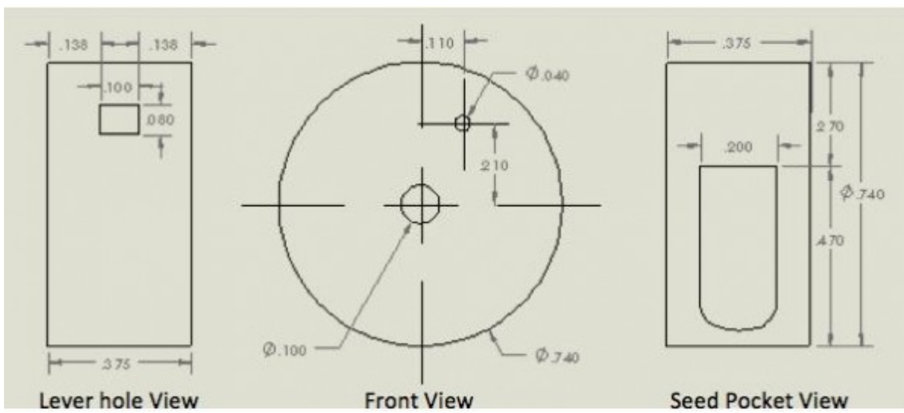

Figure 10: Left - Schematic drawings of the seeder disk which has a thickness of .375" and a diameter of .740". The disks were made of high density ABS plastic. Center - Schematic drawings of the cylinder used to hold in place the seeder disk. Right - Schematic drawing of the 50 mL conical tube used to hold the cylinder and the disks. The conical tube is also used direct dispensing of the seed.

EVALUATION

The following numerical evaluation was provided by GIENC staff. The Digger and Spacer together increased efficiency and productivity for the volunteers as well as the supervising staff. Previously, 6 volunteers out of a group of 19 were not able to participate in marking and digging the holes. With the help of the Digger and Spacer, 5 out of those 6 volunteers are now able to perform the task, thus increasing the percentage of participants from 68% (13 out of 19) to 95% (18 out of 19). Moreover, the productivity, as measured in the amount of time needed to finish digging one raised bed, has increased by more than 100%, with the completion time (45-60min) reduced by more than half (30min or less). Whereas three volunteers in wheelchairs and six elderly volunteers were previously unable to dig, all of them can now complete the task on their own using the Digger. In addition, the 1:1 supervisor-volunteer ratio in completing the task has improved to 1:7 with the help of the devices, consequently increasing the supervision productivity by 600%.

The Seeder also improves the productivity of the staff by reducing the time and seeds wasted from correcting seeding mistakes. Of the five volunteers who experienced the greatest difficulties due to limited fine motor skills, four can now perform the task with little assistance. The average time required for the volunteers to finish seeding a 48-grid tray was reduced from 15min to 11min (36% productivity increase), while for the ones with greater limitations and impaired vision, the time was reduced from 20min to 12min (67% improvement in productivity). The supervisor-volunteer ratio has also decreased from 1:1 to 1:5, with 8 out of 10 people now requiring no supervision. Furthermore, while approximately 10% of seeds were previously wasted after weeding of over-crowded seedlings, the Seeder's ability to limit only 1-3 seeds planted per hole has reduced the waste to a negligible amount, and the staff no longer needs to spend additional time removing unwanted seedlings.

Finally, the Spacer and Digger were further evaluated by staff and clients with disabilities at Wake Enterprises. For the Spacer, they mentioned that "[it] is an excellent tool for staff and participants to place plants accurately, quickly, and independently" and that " the rings allowed for accurate plant placement and more independent work with each [volunteer] but were especially appreciated by our [volunteers] with visual impairment". For the Digger, the staff commented, "[it] works well enabling the [volunteers] to not only be more accurate and efficient in their planting, but equally importantly to us here at Wake Enterprises, they can be more independent in digging a hole to the proper depth" and that "it adds a safety level for the [volunteer] by helping to keep their balance using the device instead of a shovel".

Seeder Quantitative Analysis

The objective of the quantitative analysis is to test the efficiency and accuracy of the Seeder. We performed analysis on the Seeders for both the small and large seeds. We first performed a test to see how many lever presses it took to dispense any seeds. Then, we tested how many seeds the Seeder ejected for each successful dispense. The results are shown in Figures 11 and 12. Figure 11 shows that the device fulfills our clients' desired seed resolution since 1-3 seeds were dispensed over 80% of the time while Figure 12 displays the efficiency of the Seeder, which typically required only one lever press to dispense a seed. Efficiency was best for small seeds, which were far more uniform in size than the larger beet seeds.

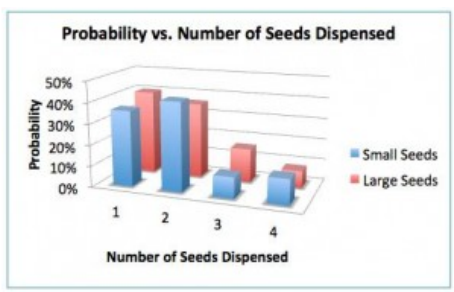

Figure 11: Our testing on the efficiency of the Seeder shows that, for both large and small seeds, the number of seeds dispensed falls predominantly in the 1-3 seed range, as desired by the clients.

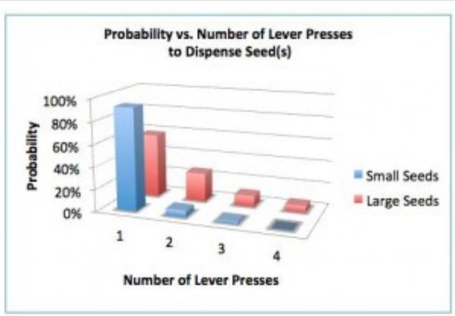

Figure 12: The second testing on the Seeder evaluates how

many lever presses are required to dispense any seeds. The data shows that the user typically only needs to press once to dispense seeds. Multiple presses were required more often for the larger beet seeds, which displayed wide variability in size.

COST AND EXPENSES

Cost of producing all three devices was $393. The Spacer materials, including the aluminum rods ($158) for the Spacer rods and arrow markers, PVC tubes for the ring markers ($20), resin nylon connectors ($78), and release pins ($35), cost $286. The Digger materials. including HDPE slates for depth indicators ($4), PVC pipes for Digger body ($16), and release pins ($10), cost $30. The Seeder materials, including torsion springs ($10), conical tubes ($2), and ABS plastic for the Seeder disk and cylinder (provided by Pratt School of Engineering, estimated $15), cost $12. Additional materials, including golf bag ($25), storage container ($10), and other hardware such as bolts nuts and washers ($30), cost $65.

CONCLUSION

The Spacer is “one of the most versatile tools made”. Our clients have “continued to use it in the raised beds and fields alike, both with great success”. “ Not only can the device be quickly assembled, but the ring and arrow markers also allow for varying degrees of support and independence. Moreover, the stand-alone ring markers of different sizes provide higher flexibility and “were especially appreciated by our participants with visual impairment.” Overall, the Spacer is a complete solution for the supervisors’ stated needs, and in their words “It’s a tool that lends itself well to flexibility”.

The Digger enables the volunteers to make a hole of accurate diameter and depth in the ground. The volunteers can simply position the end of Digger by the mark and easily push the rod into the ground with upper body strength by leaning on the handle. When asked to evaluate the usefulness of the Digger, the clients especially liked the “[depth indicator] that will be inserted and then able to be removed, to assist with depth of planting”, as “it will be beneficial to those with visual impairments and also those with special difficulties”.

The Seeder helps alleviate an otherwise tedious and time-consuming task for the volunteers and supervisors at GIENC. The Seeder now allows users to quickly dispense seeds directly into the hole with a simple press of a lever. Since the Seeder reliably dispenses only 1 to 3 seeds at a time, even those with impaired vision can operate the device. The clients mentioned that “we like the concept of the Seeder. It worked with small and large hands, alike and felt natural to use.” One limitation of the present device is the durability of the ABS plastic used in the disk and cylinder; large forces sometimes encountered due to jammed seeds can cause premature wear. Future devices should utilize a harder material such as aluminum for these parts. Overall, we have produced three working devices, each of which has multiple functions and configurations that address the varied needs of our clients. The combination of devices is robust in terms of durability of materials, number of supplied components, ease of use, and convenience of components replacement.

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ACKNOWLEDGEMENTS

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ALTERNATIVE TEXT FOR FIGURES

Figure 1: This is the complete picture of all our devices. The top left hand corner is the the spacer rods with multiple spacer rings and arrow markers attached. The bottom left hand corner are the stand alone spacer rings of different diameters. The top right hand corner are the 4 diggers with different diameters (1" and 2") and for different bed heights (ground beds and raised beds). The bottom right hand corner are the seeders.

Figure 2: Ring markers are attached to the Spacer in use on the ground beds. The Spacer intervals determine how far apart the volunteers should plant their plugs/seeds and these ring markers indicate to the volunteers exactly where to plant.

Figure 3: The various components of the Spacer are shown here. a) shows the spacing rod , which is 4" long with ¼" diameter holes spaced every 1" apart. b) shows an arrow marker, which is 1"x1"x1", with semi-circle diameter of 18/32", and a ¼"-20 bolt. c) shows a ring marker, which has a 3" diameter, with connecting L-bars and a ¼"-20 bolt. d) shows a quick release pin, with grip length 1 ¼" and diameter ¼". e) shows the L, I, and T nylon resin connectors. f) shows the 2" tall stand-alone ring markers; the smaller ring has a diameter of 2" and the bigger ring has a diameter of 4". g) shows the anchor bolts ,which are 6" long and 3/8" in diameter.

Figure 5: Figure shows the entire Digger device with the depth indicator attached. On the left is the 2" diameter ground bed Digger and on the right is the 2" diameter raised bed Digger. The depth indicators are mounted on an aluminum connector and are attached to the main Digger tube using quick release pins. They inform the user how far to push the Digger into the ground in order to make holes of desired depth. Not shown are the other two 1" diameter Diggers we provided to satisfy our client's needs for planting plugs of smaller diameters.

Figure 8: Image shows the individual components of the Seeder, as well as seeds of different sizes used for determining the dimensions of the small and large seed-disk pockets.

Figure 9: Figure shows how the seed is collected when the lever is pressed down, and then rotated to the dispensing position as the lever is released. The spring leg pushes against the disk screw to provide the force for counterclockwise rotation.

Figure 11: Our testing on the efficiency of the Seeder shows that, for both large and small seeds, the number of seeds dispensed falls predominantly in the 1-3 seed range, as desired by the clients.

Figure 12: The second testing on the Seeder evaluates how many lever presses are required to dispense any seeds. The data shows that the user typically only needs to press once to dispense seeds. Multiple presses were required more often for the larger beet seeds, which displayed wide variability in size.

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