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Design and Performance Test of Corn Seeder Integrated with Fertilizer Applicator

Muhammad Asshiddiq Ansar[1], Ansar[1,✉], Gagassage Nanaluih De Side[1]

[1] Department of Agricultural Engineering, Faculty of Food Technology and Agroindustry, University of Mataram, INDONESIA.

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Corresponding Author:
✉ ansar72@unram.ac.id
(Ansar)

ABSTRACT

Along with the increasing demand for corn in the country, the use of agricultural tools and machines to increase corn productivity is very important. Therefore, this study aims to design and test the performance of a corn seeder integrated with fertilizer applicator. This tool is designed using the principles of agricultural mechanics. The research stages began with conducting a feasibility study, designing a prototype of the tool, then conducting performance testing on agricultural land. The results showed that the majority of farmers considered this tool very effective and efficient to use compared to a digging tool. The results of the performance test on farmers' land also showed that this tool was able to plant corn seeds with uniform depth and spacing and distribute fertilizer evenly. All components of the corn seeder function properly, so it is suitable for use to increase the productivity of corn farmers' land. This corn seeder has met the category requirements as a corn seeder and fertilizer applicator with a manual operating system. The application of this corn seeder has the potential to increase land productivity and can facilitate the process of planting corn seeds.

1. INTRODUCTION

The need for corn in Indonesia always increases every year, but domestic production has not been able to meet national needs (Amalia *et al*., 2020). National corn production in 2023 only reached 236.22 thousand tons/year, while the need reached 541.52 thousand tons/year, so the shortage was met by imported corn (Purba & Sinaga, 2024). The fact that domestic corn needs continue to increase every year should be a motivation for farmers to continue running corn farming businesses and increase production volumes (Hermawan *et al*., 2012). In order to meet the needs of corn consumption for the community, land productivity for corn planting must be increased. Ansar *et al*. (2023) have reported that to increase land productivity, there are several things that must be considered, including the distance between seeds should not be too far apart or too close together. If it is too far apart, it can cause land waste and conversely, if the planting distance is too close, there will be competition for nutrient sources in the plant roots. Another implication is that the size of the corn plant growth is not the same and the harvest period of the plant is hampered (Soyoye *et al*., 2016).

Corn plants are very strategic to be developed at this time. In addition to having high economic value, corn can also be used as the second largest source of carbohydrates and protein after rice (Virk *et al*., 2020). Corn self–sufficiency can be realized if supported by agricultural mechanization equipment as a solution to the limited workforce and the low enthusiasm of young people to pursue agricultural professions (Wang *et al*., 2022).

Several research results have reported that the design and development of agricultural tools and machines is one of the efforts to increase the production capacity of agricultural land (Hajad *et al.,* 2021). A seed planter is a tool that can facilitate the process of planting seeds in the field (Liu *et al*., 2018). On small–scale land, seed planters with human thrust can be used effectively and efficiently. This seed planter can adjust the planting hole with a certain distance and depth according to your wishes (Ansar *et al*., 2021).

Corn cultivation requires a series of long activities, such as the process of plowing the land, followed by the process of planting, weeding, and fertilizing (Santoso *et al*., 2021). The time and energy to carry out this fertilization process are also long (Ansar *et al*., 2021). However, if the planting process is carried out with equipment that is integrated with fertilizer applicator, time and energy can be saved and operational costs can be reduced. Therefore, integration between corn seeder and fertilizer applicator is very important to improve performance and efficiency of time and labor. Thus, the aim of this study was to design and performance test of corn seeder integrated with fertilizer applicator. This research produces a corn seeder that is useful for increasing the efficiency and effectiveness of the corn seed planting process, thereby shortening the cultivation duration and increasing land productivity.

2. MATERIALS AND METHODS

2.1. Materials and tools

The main materials used for this study were iron pipes, bolts and nuts, polyvinyl chloride (PVC) plastic, and acrylic. The supporting materials needed were welding electrodes, putty, paint, and sandpaper. The production equipment used was an electric welding machine, a drill, a hacksaw, and a wrench. While the measuring instruments for the study were a digital tachometer, digital scales, a stopwatch, a measuring tape, and a roll meter. The test sample used was Bisi variety corn seeds that had been shelled.

2.2. Research Stages

Research activities are carried out in 4 stages, namely: (1) feasibility study stage, (2) tool design stage, (3) field performance testing stage, and (4) evaluation stage.

2.2.1. Feasibility study stage

The feasibility study stage uses a questionnaire method to obtain information related to the technical and economic needs of the tools needed by farmers. The data collected are in the form of specifications of existing corn seeders, specifications of planted seeds, analysis of farmer efforts, and land characteristics at the research location. The data is used as the basis for designing of corn seeder integrated with fertilizer applicator.

2.2.2. Tool design stages

The corn seeder design stage is made with the help of solid work software to display 3–dimensional images (Figure 1a and 1b). The dimensions of the tool are adjusted to the data of corn seeder tools commonly used by farmers. The dimensions of the seed container box and seed release hole are adjusted to the characteristics of the seeds used by farmers. The assembly of the corn seeder was carried out at the Agricultural Power and Machinery Laboratory, Faculty of Food Technology and Agroindustry, University of Mataram.

2.3. Performance test stages

The performance testing of corn seeder integrated with fertilizer applicator (Figure 1c) was carried out in rice fields (35 x 55 m^2). Field testing was focused on getting feedback from farmers regarding the design offered. Each farmer were asked to try this corn seeder on the land they own. After that, farmers were asked to provide an assessment. Some parameters for the performance test of corn seeder integrated with fertilizer applicator were:

1. Tool thrust load: The thrust load or thrust force (Fd) of the corn seeder integrated with fertilizer applicator was derived from Suryono (2014) as the following:

$$Fd = WBa + WPu + WRa \quad (1)$$

where WBa is corn seeder weight (10.8 kg), WPu is fertilizer weight (capacity 5 kg), and WRa is seed weight (kg).

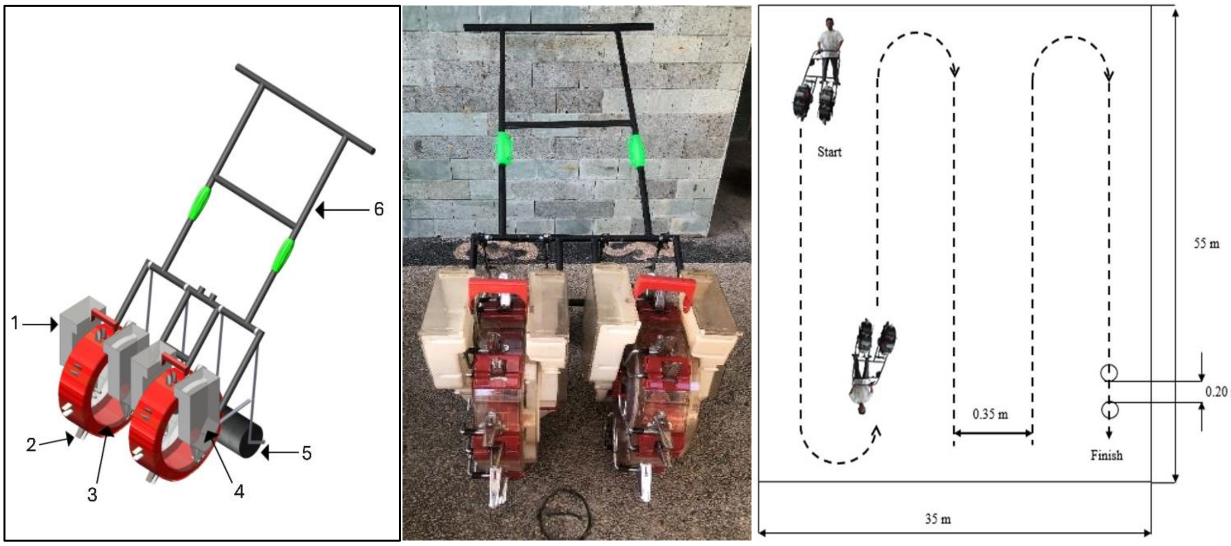

Figure 1. Corn seeder integrated with fertilizer applicator: (a) Design, (b) Product equipment, (c) Performance test. (Note: Annotation: [1] Seed container, [2] Furrow opener, [3] Seed metering device, [4] Fertilizer container, [5] Covering device, [6] Handle).

The thrust force of the corn seeder is influenced by the weight of the chisel and the wheel resistance force (*Fs*) which can be calculated using the following equation (Pangalila *et al*., 2020):

$$Fs = \mu . N \tag{2}$$

where μ is coefficient of friction against the ground (= 0.40), and *N* is normal force whose value is the same as the total weight of the tool (21.8 kg), but in the opposite direction.

2. Corn seed weight: The average weight of corn seeds is needed to determine the amount of corn seeds needed per hectare. The average weight of corn seeds was calculated using 10 seeds (Chen *et al*., 2022).

3. Fertilizer weight: Calculation of fertilizer weight is important to determine the fertilizer requirements according to the standards for each hectare of land. The right way to fertilize corn is the key to success in producing a high corn harvest. However, fertilizer must also be provided according to plant needs. The ideal amount of fertilizer required for corn plants is 50 kg/ha (Permanasari & Kastono, 2012).

4. Planting speed: Planting speed is needed to estimate the planting and fertilization time on a hectare (10,000 m^2) basis. Planting speed (*V*) was calculated from a traveled distance (*S*) within time (*t*) as follows (Han *et al*., 2022):

$$V = S/t \tag{3}$$

5. Planting space: Planting distance in rows and between rows must be arranged in such a way as to obtain high land productivity. The ideal planting distance in rows and between rows follows the recommendations of the research results of Wang *et al*. (2022), which was 20 x 35 cm.

6. Number of seeds per hole: The ideal number of seeds per planting hole only contains one seed. If more than one, there will be a waste of seeds and the plants will easily collapse (Audah *et al*., 2017).

2.4. Data Analysis

The data needed in this study are feasibility study data, planting distance in rows and between rows, number of seeds and fertilizers per planting hole. The data is displayed in graphical form to determine the relationship between design parameters and corn seeder performance (Djoyowasito *et al.*, 2017).

3. RESULTS AND DISCUSSION

3.1. Seeder Performance Test

The results of the field performance test are presented in Figure 2. This performance test focused on determining the planting distance in rows and between rows, the depth of the planting hole, and the number of seeds in each hole. Based on the figure, it can be seen that the corn seeder integrated with fertilizer applicator can function well. This tool can release corn seeds and fertilizers according to the standard fertilization dose.

Figure 2. Equipment testing in the farmer's fields

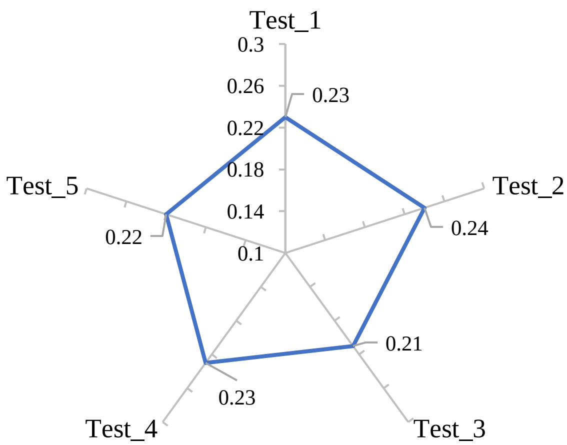

Figure 3. Results of measuring the distance between plants in rows and between rows.

3.2. Plant Spacing in Rows and Between Rows

The results of measuring plant spacing in rows and between rows are presented in Figure 3. The figure shows that the plant spacing in rows is 0.23; 0.24; 0.21; 0.23; and 0.22 cm and the plant spacing between rows is 0.35; 0.36; 035; 0.35, and 0.36 cm. The plant spacing in rows and between rows varies due to the uneven land surface, so that the plant spacing in rows and between rows sometimes changes along with the rotation of the wheel. However, the plant spacing in rows and between rows is still close to the recommended 20 cm and 35 cm (Bolly, 2018).

The distance between plants in rows and between rows is one of the factors that affect land productivity. Previous researchers Li *et al.* (2023), have also reported that one of the causes of low land productivity is the less than optimal distance between plants in rows and between rows. The distance between plants that is too close can cause leaves on the same plant to shade each other, so that plant growth is hampered. In addition, competition for nutrients between plants is also very high (Han *et al*., 2022).

Corn plant growth can be maximized by adjusting the distance between plants in rows and between rows (Karima *et al*., 2013). The same thing has also been explained by Amalia *et al.* (2020), that if the distance between plants is too close, the leaves of the plants can shade each other, reducing the intensity of light received by the lower plants. This can inhibit the photosynthesis process and reduce biomass production. Excessive plant populations can have various negative impacts on the growth of the plants themselves, such as plant roots competing with each other to absorb water and nutrients from the soil. If it is too close, some plants will lack nutrients so that their growth is hampered.

The distance between plants that is too wide can increase the growth of individual plant roots, but provides an opportunity for weeds to grow in the gaps between plants (Sitorus *et al.*, 2015). Corn plants accompanied by weed growth can be detrimental because there is competition in the use of nutrients, water, light, and growing space. The distance between plants that is too wide can not only reduce the number of plant populations but also reduce the use of sunlight and plant nutrients, because some of the solar radiation only falls on the soil surface and nutrients can be lost due to evaporation (Sianipar & Fatoni, 2019). Syafa'at & Subantoro (2017), also reported that the distance between plants that is too close can interfere with growth, but if it is too loose it can reduce the plant population per unit area.

3.3. Planting Depth

The results of the planting hole depth measurement can be seen in Figure 4. This figure shows that this planter can form a planting hole and insert corn seeds directly into the hole and close the hole again. The depth of the planting hole ranges from 4–7 cm. There are deep planting holes, but there are also shallow ones. The varying depths of the planting holes are caused by uneven land conditions because the soil processing process is not carried out perfectly.

The ideal planting hole depth based on the results of Sitorus *et al.* (2015) is 4–7 cm because it can produce perfect seed germination. Seed plants that are too deep can cause poor germination. The depth of the planting hole for good corn seeds according to Wirawan *et al.* (2018), ranges from 5–7 cm because it can produce moisture in the planting medium that can be used to actively metabolize. The results of Probowati *et al.* (2014) also reported that shallow planting holes can cause seeds to not be firmly planted because the roots are not deep enough. The heavy load due to the seed coat being lifted to the surface of the soil can cause the seeds to fall easily when exposed to water.

The depth of the seed planting hole also affects the growth and development of plant roots. Thus, the depth of the seed planting hole is very important to note so that the germination process can take place properly. The depth of corn seed placement that is commonly used in Indonesia is 5–7 cm (Ansar *et al*., 2023).

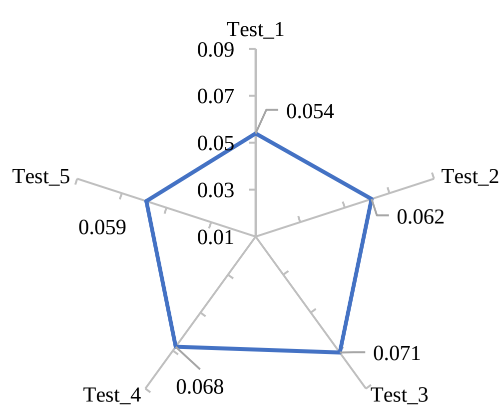

Figure 4. The results of the plants hole depth

3.4. Number of Seeds each Planting Hole

The results of observations of the number of seeds per planting hole are presented in Figure 5. The figure shows that the number of seeds per hole varies between 1–2 seeds, while the expected number of seeds is only 1 seed per hole. Actually, the seed rationing plate has been designed by shifting the rotor casing to adjust the size of the corn seed diameter, but the seed rationing process has not been as desired. The varying number of seeds per planting hole is thought to be caused by the shape and diameter of the corn seeds which are not uniform. Another factor is that there is no implement agitator, so there is a buildup of seeds on the metering device. The seeds fall into the planting hole only because they are influenced by the weight of the seeds and the earth's gravity.

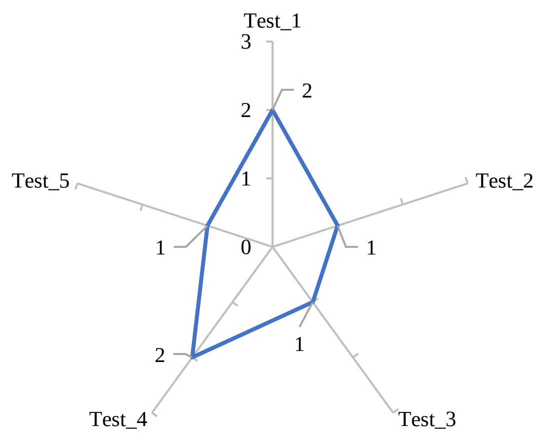

Figure 5. The number of seeds each planting hole

The seed rationing tool is the most important part of this corn seeder integrated with fertilizer applicator because it functions as a regulator of the regular fall of seeds into the planting hole. This tool is driven by the rotational power of the wheel by rotating the axis of the planting unit, so that the seeds can fall based on the earth's gravity. The results of the study showed that the performance of the seed dispensing tool has worked well because it is able to place seeds in the soil with an average of one seed.

Seeds planted in large numbers in one hole can trigger competition for sunlight. Conversely, if the number of seeds per planting hole is small, the plant population will not be optimal, causing low land production (Ansar *et al*., 2024). Likewise, the number of seeds per planting hole must also be considered in corn cultivation. An excessive number of seeds per planting hole cannot provide optimal results. In order for the growth and development of corn plants to be optimal and produce high yields, the number of seeds per planting hole must be properly regulated. The more seeds per planting hole, the greater the need for nutrients.

3.5. Feasibility Study

Feasibility of the tool is based on respondent opinion. The respondents are local farmers with education levels as presented in Figure 6. Based on the data on the level of farmer education, it is known that most respondents have elementary school education (45%), junior high school (47%), only a small number have graduated from high school (8%). In terms of age, most respondents are in the age range above 50 years. This age range really needs planting aids that can help speed up the process of planting corn seeds.

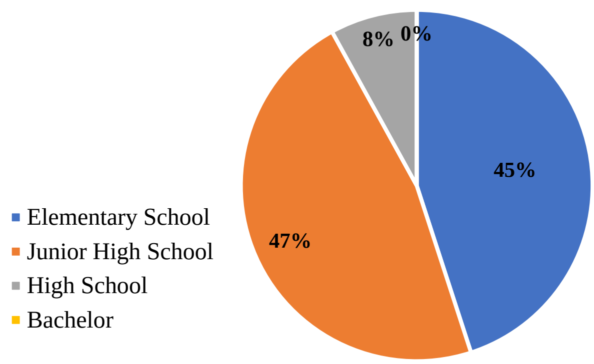

Figure 6. Education level of respondents

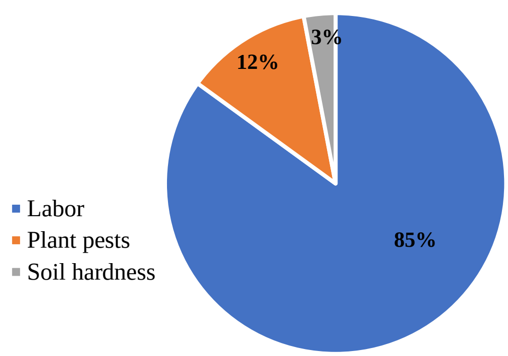

Figure 7. Conditions constraining farmers at the research location.

Another important fact related to farmers in cultivation corn is constrain conditions. The data in the Figure 7 shows that 85% of farmers are constrained by the availability of labor, 12% are related to pests and diseases, and only 3% are related to the condition of the soil surface during the dry season which is too harsh. A fact that 85% of farmers face labour problems is beneficial for developing an efficient planting equipment.

Results of our survey reveal that majority of respondents (49%) accepted the prototype corn seeder integrated with fertilizer applicator that had been designed because it was more effective and efficient in use compared to a hoe. However, the obstacle was its high price. Only 5% of respondents were willing to buy this corn seeder integrated with fertilizer applicator (Figure 8).

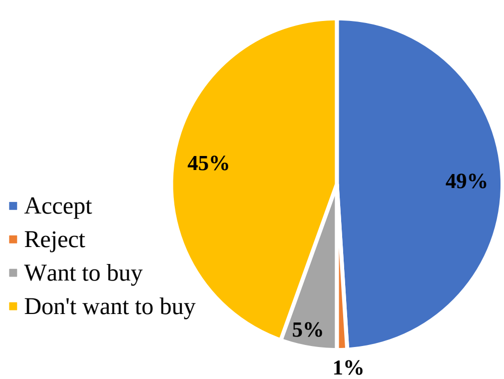

Figure 8. Respondents acceptance of corn seeder integrated with fertilizer applicator

3.6. Economic Benefit of Corn Farming

The results of the farming analysis at the research location showed that the average corn farming margin in Central Lombok Regency was IDR 1,207,500 per hectare. If the area of land cultivated by farmers is 5 ha, then the corn business margin only reaches IDR 6,037,500 for a planting age of 90–100 days. This shows that the economic value of corn farmers is still relatively low.

The results of measuring the hardness of the soil surface at the research location obtained data that the hardness of the soil in the dry season still varies between 50–110 N/cm^2. This shows that the surface layer of the soil in several locations has hardened so that farmers have difficulty planting corn seeds in the dry season. Farmers make planting holes with a depth of between 4–7 cm, then corn seeds are inserted into the planting hole. Each planting hole is filled with 1–2 seeds. The reason for farmers to use manual sowing tool (*tugal*) is because of low price, ranging from IDR 75,000 to 100,000. Measurement of the dimensions of this *tugal* tool is used as a basis for consideration in designing the planting mouth to be developed.

Information obtained from the feasibility study related to the technical needs, economic, social, and cultural aspects of farmers are used as considerations for designing corn seeder integrated with fertilizer applicator. Figure 1 shows the structure of the corn seeder integrated with fertilizer applicator. This tool consists of 6 main components, namely a collection box, a seed rationing tool, a planting mouth, a control lever, a furrow cover, and a control bar.

4. CONCLUSION

The design results of corn seeder integrated with fertilizer applicator can help farmers to plant and fertilize simultaneously in one work process. The results of the feasibility study showed that most respondents (85%) considered the use of this tool is more effective and efficient compared to using a digging tool. The results of the field test also showed that the performance of the tool was very good for planting at a planting hole depth of between 4–7 cm. The average content of the planting hole is one seed per hole. All components of the corn seeder can work well for planting and fertilizing corn seeds. In an effort to increase land productivity, the use of this corn seeder is identified as one of the promising solutions. In order to optimize labor and time efficiency, it is necessary to integrate this tool with the tractor engine through a coordinated system.

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