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# A Prototype Harvester For Chickpea Harvesting

## Nohut İçin Bir Prototip Hasat Makinesi

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**ABSTRACT**

To meet the needs of Iranian farmers who grow rainfed chickpeas, a new harvester was developed and tested. The project began with a modified stripper harvester and continued with a new design. The main components of the machine, such as the platform, reel, chassis and power transmission system, were improved to enhance its work quality. The harvester, which is pulled by a tractor, uses a power take-off-powered reel with 6 bats and a diameter of 700 mm to hit the pods and detach them from the plants. The best results were achieved when the reel speed was 2.4 times the forward speed of 3 km/h. The harvester could cover 0.42 ha/h and collect 120 kg/h of pods with a working width of 1.4 m. The machine performed well in field trials, with low purchase and operation costs, acceptable efficiency and losses, and better outcomes than existing methods and machines for chickpea harvesting.

**Keywords:** Chickpea, design, harvester, harvesting losses, reliability, stripper header

**ÖZ**

İranlı çiftçilerin yağmurlama sistemlerinde nohut yetiştirmeleri ihtiyaçlarını karşılamak amacıyla yeni bir hasat makinesi geliştirilmiş ve test edilmiştir. Proje, modifiye edilmiş bir şerit hasat makinesi ile başlamış ve yeni bir tasarım ile devam etmiştir. Platform, makara, şasi ve güç iletim sistemi gibi makinenin ana bileşenleri, çalışma kalitesini artırmak için iyileştirilmiştir. Traktör tarafından çekilen hasat makinesi, nohudu bitkilerden ayırmak için 6 sopaya sahip, çapı 700 mm olan bir güç alımıyla çalışan makarayı kullanmaktadır. En iyi sonuçlar, makara hızının 3 km/s hızındaki ileri hareket hızının 2.4 katı olduğunda elde edilmiştir. Hasat makinesi, 1.4 m çalışma genişliği ile saatte 0.42 ha alanı kapsayabilir ve saatte 120 kg nohudu toplayabilir. Makine, düşük satın alma ve işletme maliyetleri, kabul edilebilir verimlilik ve kayıplar, nohut hasatı için mevcut yöntemler ve makinelerden daha iyi sonuçlar elde etmiştir.

**Anahtar Kelimeler:** Nohut, tasarım, hasat makinesi, hasat kayıpları, güvenilirlik, şerit hasat başlığı

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## Introduction

Rainfed chickpeas (Cicer arietinum L.) are grown in fallow fields of developing countries and harvested by hand. But in recent years, labor costs have risen due to smaller families and rural youth migration. This has led some farmers to abandon their fields or crops. Using conventional grain combine harvesters for chickpeas is not feasible (Bansal & Sakr, 1992; Haffar et al., 1991; Sidahmed & Jaber, 2004) because of high grain losses. According to farmers and unofficial statistics, up to 50% of the yield can be lost by using combine harvesters. To reduce harvesting losses in pulse crops, plant movement during harvesting should be minimized and headers that follow the ground and capture low pods should be used (Siemens, 2006).

Detaching pods from the anchored plant without harvesting the straw was applied for reducing losses. Behroozi-Lar & Huang (2002) applied the Shelbourne Reynolds stripper header, which was developed at the Silsoe Research Institute, UK and commercially produced by the British manufacturer Shelbourne Reynolds Engineering Ltd., for chickpea harvesting. It uses the transverse rotor principles in which stripping of the crop takes place along the whole length of the rotor (Tado et al., 1998). The main disadvantage of the stripper headers is that they have excessive losses in low harvest yield and/or immature crops. Therefore, the application of the stripper header for chickpea harvesting was an unsuccessful attempt in compliance with losses.

To reduce losses, pods were detached from the plant without harvesting the straw. Behroozi-Lar & Huang (2002) used a Shelbourne Reynolds stripper header for chickpea harvesting. This header was developed at the Silsoe Research Institute, UK, and produced by Shelbourne Reynolds Engineering Ltd. It strips the crop along the length of the rotor (Tado et al., 1998). The main drawback of the stripper headers is that they lose too much crop in low yield or immature conditions. So, using a stripper header for chickpea harvesting did not work well in terms of losses.

In 2006, Golpira (2015a,b) surveyed and published the crop properties of Reynolds number, terminal velocity, sphericity, dimensions, densities, mass, volume hardness, impact velocity, coefficient of friction, and drag force. Golpira et al. (2013) developed a tractor-pulled harvester with a modified stripper header for chickpea harvesting. The header had a platform with forward-opening fingers that stripped the plants as they moved through the V-shaped slots. The platform also supported passive fingers and delivered the harvested material. A reel with three bats and a diameter of 60 cm pushed the pods and the top of the chickpeas over the header. A chain and a sprocket system controlled the reel speed from 30 to 110 rpm. A conveyor with an endless chain collected the harvested material and lifted it to a sacker unit 1 m above the ground. The modified stripper harvester had drawbacks such as high weight, high losses, poor maneuverability, and low reliability.

Golpira (2013) tried to reduce the losses of the modified stripper harvester and made a new machine. The goals were to improve the machine performance and reliability by 1) using a pneumatic conveyor for more flexibility, 2) optimizing the platform to lower losses, and 3) using a three hitch point chassis for better maneuverability. The stripper header for chickpea harvesting had a platform 1.4 m wide with 27 V-shape teeth, a reel with 6 bats, a diameter of 700 mm, and a kinematic index of 1.8. The floating header, which followed the ground level, reduced the pods left on the plant, but the platform losses were still high. To avoid the high time and cost of conventional design, a soft simulator was developed for optimizing the platform structure. Fuzzy modeling and genetic algorithm were combined with the experience-based data to create a virtual model. The result was an optimized platform that was used on the harvester presented in this research. This automatically generated harvester was later published by Golpira and Golpira (2017).

Both the modified stripper harvester and the redesigned chickpea harvester work based on stripping technology, where fingers of a platform detach pods from plants and a reel delivers harvested material. Six years of modification and trial have exhibited no acceptable working quality in regards to the mass of pods collected from the ground and those remaining on the plant after harvest. Furthermore, the reliability of the machines was not sufficient to support commercialization of the methodology and mechanism. The designer's knowledge reveals that the reel would harvest pods with fewer losses than the platform. Additionally, the design of a new concept with 1) an off-set and a semi-mounted chassis and 2) a power take off (p.t.o.)-powered reel is a feasible strategy for increasing reliability and reducing losses. These improvements enhance the methodology and mechanism applied in the chickpea harvesters for increasing harvesting performance.

This research developed and tested a tractor-pulled harvester for rainfed chickpea pods. The machine's reliability and losses were enhanced over 3 years of modification and field trials. Checking the purchase price and fixed costs of the concept can help to market the prototype.

## Methods

### Header Design

The harvesting works by a reel that hits the plants to take off the pods and toss them into a collection container (Figure 1). The platform with passive fingers and V-shaped slots holds and guides the plants for harvesting. Tire wheels make the platform move gently and lower shattering losses. The reel, with six bats and a diameter of 700 mm, removes pods from the plants. A key condition for reel performance is that the ratio of peripheral forward speed must be higher than the unit. The reel speed is calculated by:

$$v = \frac{\pi D n}{60} \quad (1)$$

where

v: tangential speed of reel (m/s)

*n*: reel speed (rpm)

*D*: reel diameter (m)

According to Eq. [1], the reel forward speed is 2.1 m/s (7.2 km/h) for the reel diameter of 0.7 m and a reel speed of 55 rpm.

Kinematic index of the reel can be calculated as follows:

$$\lambda = \frac{v}{V} \quad (2)$$

where

*V*: forward speed of harvester (m/s)

λ: kinematic index (dimensionless)

According to Eq. [2], the kinematic index of the reel is 2.4 for the forward speed of 3 km/h and the reel speed of 7.2 km/h

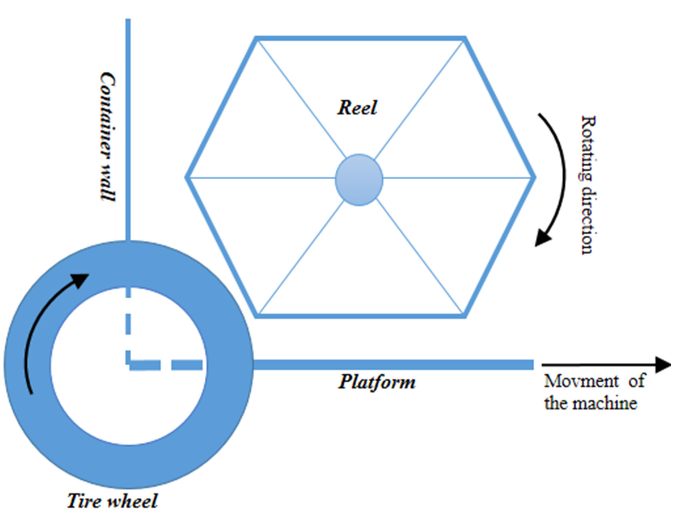


**Figure 1.**
*Schematic drawing of the machine including main components and arrows indicating the movement of the machine and the reel.*

### Chickpea Harvester

The harvester for chickpea pods was tractor-pulled and had a semi-mounted and off-set chassis (Figure 2). It had a platform, a reel, a power transmission system, and tire wheels. A variable transmission system with a gearbox, a pulley, and a belt gave different reel speeds and kinematic indexes. The p.t.o.-power was transferred to the reel shaft. Two tire wheels with adjustable screws set the platform height from 0 to 150 mm. The platform angle was adjusted by semi-mounted linkage to avoid soil entry. The machine was 2500 mm wide and 1400 mm wide for working. It weighed 350 kg. The machine characteristics such as reel and platform sizes, gearbox and pulley system drive ratio were provided in Table 1. The laborer manually removed the harvested pods from the collection container. A pneumatic conveyor was made for material handling, but it was not on the machine in this design stage. This made the machine light and maneuverable to lower harvesting losses.

### Machine Evaluation

The concept evaluation had two experiments. The first trial modified and adjusted the machine and tested its reliability. The final evaluation measured the harvesting losses with different reel kinematic indexes. The goal was to improve the machine's harvesting performance with modifications and adjustments. The first experiment was done in two sites of Dooshan farm of the University of Kurdistan in the summers of 2013 and 2014. Before the experiments, the working height was set at 5 cm (above the ground) to lower losses and soil entry (Table 2). Two adjustable screws fixed the vertical and horizontal distance between the reel bats and fingers at 1 cm so that the platform with passive fingers was not stuck by the stems and weeds. The platform angle was zero degrees. Also, the harvester ran at an average forward speed of 3 km/h for all the experiments.

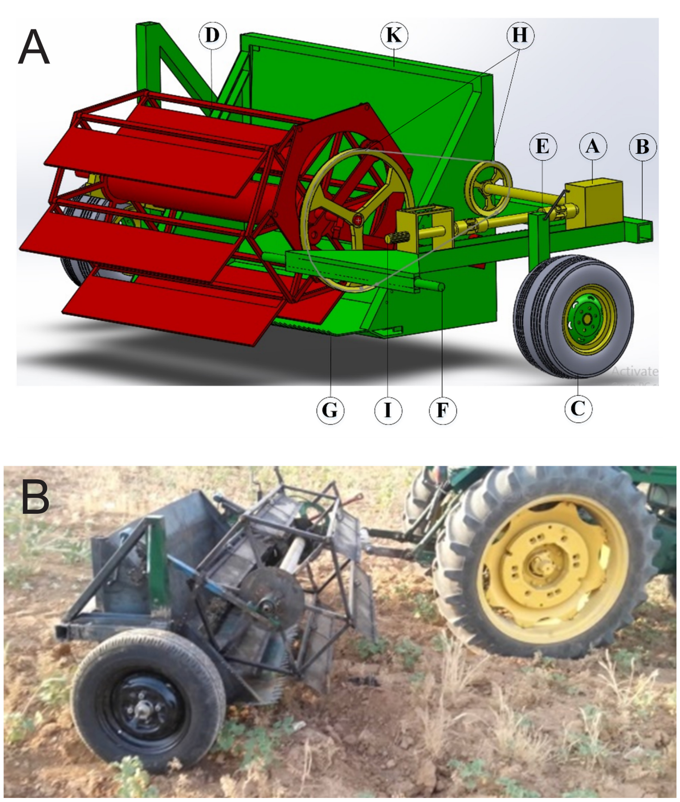


**Figure 2.**
*A) Three-dimensional model of the prototype harvester: A, gearbox; B, chassis; C, ground-wheel; D, reel; E, adjustable screw; F, semi-mounted linkage; G, platform; H, driver and driven pulleys. B) Prototype harvester in the working position.*

**Table 1.**
*Key Variables of the Chickpea Harvester*

| Variable | Default Value |
|---|---|
| Reel | |
| Length (mm) | 1400 |
| Diameter (mm) | 700 |
| Number of bats on reel (dimensionless) | 6 |
| Gear box ratio | 1 : 1 |
| Pulleys ratio | 1 : 3 |
| Platform | |
| Length (mm) | 600 |
| Width (mm) | 1400 |
| Thickness (mm) | 6 |
| Chickpea harvester | |
| Weight (kg) | 360 |
| Working width (mm) | 1300 |
| Machine length (mm) | 1300 |
| Total width (mm) | 2500 |

A designer wants to know how reliable a product is when it is new. This depends on its design and how it is made (Cruse, 1997). For a concept like the machine in this research, the concept of reliability was used for evaluation. Reliability is important for commercial or prototype machines. The concept of reliability evaluation is based on the designer's sense of hearing noises, seeing operation, and feeling vibration. The driver (designer) stopped the tractor when he felt he needed to check the machine. He checked, adjusted, and fixed the belts, the transmission shaft, and the pulleys during operation. These times were downtimes. The harvester ran for 50 m in the field and the time for crop harvesting was measured. The total time of operation was split into 1) theoretical time and 2) downtimes. The time for adjusting, repairing, attaching or detaching, and other downtimes in 50 m of rows were measured to find the concept reliability of the machine. The operational reliabilities were one minus the downtime probability in decimal form.

### Harvesting Losses

The second experiment, field trial, tested the harvesting losses of the concept. Reel speeds of 45, 55, and 65 rpm, i.e., kinematic indexes of 2, 2.4, and 2.8 were used in the field. A fallow field of chickpea near Sanandaj was planted with a common chickpea variety, Kabuli. A hectare was plowed and disk-harrowed for

**Table 2.**
*Operators of the Prototype Harvester*

| Value | Default Variables | Variable |
|---|---|---|
| 3 | 3–6 | Forward speed (km/h) |
| 5 | 0–15 | Working height (cm) |
| 0 | 0–5 | Platform attack angle (degree) |
| 1 | 0–5 | Horizontal distance (cm) |
| 1 | 0–4 | Vertical distance (cm) |

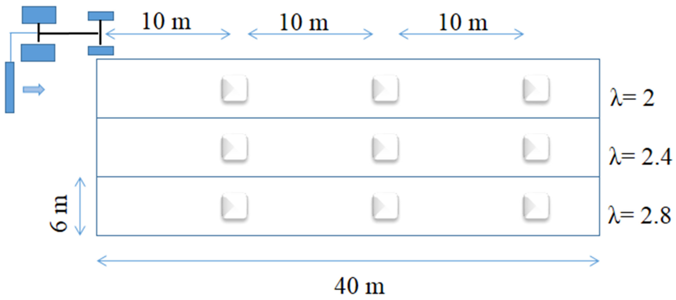


**Figure 3.**
*Schematic drawing of experimental design and sample area for measuring harvesting losses.*

chickpeas. An area of 40 m × 18 m was chosen for trials. The area was split into three blocks of 6 m width, with three plots in each block (Figure 3). Each plot was a square of 70 cm side for measuring losses. Before harvesting, sample frames were placed on the ground. Pre-harvest losses were measured and recorded by collecting the seeds and pods on the ground from the samples. Before harvesting, pods on the plants in the sample areas were measured to find total losses. Grains were separated from other material by a traditional threshing and cleaning method where tractor wheels pressed material on asphalt and then wind cleaned it manually.

The harvester ran, and total losses were measured after harvesting. Pods left on the plants and those scattered on the ground in the sample area were collected (Table 3). Losses include the pods that the header shattered ($L_S$) and those that stayed on the plant ($L_P$) calculated by this equation:

$$L = \frac{L_P + L_S}{L_P + L_S + H_P} \times 100 \qquad (3)$$

where *Hp* is the number of harvested pods, $L_s$ is the number of pods on the ground, and $L_p$ is the number of pods on the plant after harvesting.

Cost and time limits and the dry year in the study area were the challenges for the evaluation. These factors limited the replication and losses data, but it was the only way to test. All the loss experiments were done as factorial based on a completely randomized design in three replications. The blocks had the same condition, so their effect was ignored. The data were analyzed with variance analysis to find the losses. The means of the treatments were compared with Duncan's multiple range tests at a 5% level for the losses.

## Results

Operational reliability is the chance that a machine will work well under certain conditions at any time (ASAE, 2000). The simple structure of the chickpea harvester helps to achieve reliability. The reliability of many components is the product of the individual chances. Based on the theoretical and actual times calculated and measured, the machine reliability was 66% (Table 4). With a forward speed of 3 km/h, the machine travels 50 m in 60 seconds, which is the theoretical time. The reliability of the machine can affect field capacity in two ways: 1) raising the average forward speed of the tractor, 2) increasing field efficiency by reducing machine breakage and downtimes.

**Table 3.**
*Data Showing Losses for Different Reel Kinematic Indexes*

| Reel Kinematic Index | Shattering Losses (%) | Remained Pods on Anchored Plant (%) | Total Losses (Remained +Shattered) (%) |
|---|---|---|---|
| 2 | 13 | 8 | 23 |
| | 15 | 5 | |
| | 17 | 11 | |
| 2.4 | 14 | 3 | 20 |
| | 15 | 6 | |
| | 16 | 6 | |
| 2.8 | 25 | 4 | 35 |
| | 31 | 4 | |
| | 34 | 7 | |

### Machine Performance

The analysis shows that pods left on the plant are not different for reel kinematic indexes of 2, 2.4, and 2.8. The bats' force is enough to take off pods from the plant and toss them to the container. But total and shattering losses are different for different reel kinematic indexes (Table 5).

The reel bats take off pods from the plants and also move pods and other material to lower pod-shattering on the ground. More kinematic indexes make the reel and pods move at a higher speed, which increase the chance of shooting harvested materials out of the container, leading to increased losses. Data show that the lowest losses were found when the reel index was 2 or 2.4. The lowest losses of 20% of the total yield were found for a kinematic index of 2.4, a forward speed of 3 km/h, and reel speed of 55 rpm. This loss shows the good performance of the concept

**Table 5.**
*Data Showing Losses for Different Reel Indexes*

| SV | Df | Ss | Ms | Fs |
|---|---|---|---|---|
| Replication | 2 | 450 | 225 | $25.95^{**}$ |
| Error | 6 | 52 | 8.67 | |
| Total | 8 | 502 | | |

**Table 4.**
*Comparing Reliability of the Fabricated Chickpea Harvesters*

| Factors | | | | | |
|---|---|---|---|---|---|
| Machine | Theoretical Time (s) | Actual Time (s) | Downtime Probability (Decimal) | Reliability (Decimal) | Reliability (%) |
| Prototype harvester | 60 | 90 | $0.33 = \frac{90-60}{90}$ | $1-0.33=0.66$ | 66 |

| Table 6. *Physical Properties of Chickpea (Kabuli) During Harvesting* | | | |
|---|---|---|---|
| **Crop Properties** | **Mean Values** | **Range** | **SD** |
| Plant height (m) | 22 | 15–30 | 0.5 |
| Moisture content (% w.b.) | 15 | 10.5–17 | 1.5 |
| Number of pods (per plant) | 7 | 2–16 | 2 |
| Number of bushes (per m$^2$) | 4 | 0–5 | 1 |

in terms of both the pods on plants and shattering losses. This reel speed is suitable for plants' distance of 15 cm in rows or more.

The plants in the study area are spaced more than 50 cm apart, which allows the forward speed to vary depending on the terrain and crop characteristics. The height of the anchored plant, which influences the losses, ranged from 12 to 28 mm in the field (see Table 6). The total yield was 300 kg/ha, which is normal for this region.

### Economic Aspects

The design would focus on economic factors, such as field capacity, ownership cost, and purchase price, rather than technical ones. The work rate was 0.42 ha/h, calculated by: for a forward speed of 3 km/h and a working width of 1.4 m (Eq 4).

$$3\left(\frac{km}{h}\right)\times 1.4(m)\times 1000\left(\frac{m}{km}\right)\div 10000\left(\frac{m^2}{ha}\right)=0.42\left(\frac{ha}{h}\right) \quad (4)$$

The harvester has an actual field capacity of 0.25 ha/h, assuming a field efficiency of 60%. This is 16.6 times faster than manual harvesting by a worker. The machine can harvest 150 hectares in a year, working for 10 hours a day, 30 days a month, and 2 months a year, based on Eq. 5.

$$0.25\left(\frac{ha}{h}\right)\times 10\left(\frac{h}{day}\right)\times 30\left(\frac{day}{month}\right)\times 2\left(\frac{month}{year}\right)=150\left(\frac{ha}{year}\right) \quad (5)$$

The equipment costs \$2000, which will be recovered over the harvester's economic life (10 years). The depreciation cost of the machine was calculated using a straight-line method and ignoring the salvage value, since the machine is simple and light. The depreciation cost of the machine is 1.33 \$/ha, according to Eq. 6.

$$200\left(\frac{\$}{year}\right)\div 150\left(\frac{ha}{year}\right)=1.33\left(\frac{\$}{ha}\right) \quad (6)$$

The cost of shelter, insurance, and taxes is about 2.5% of the machine's original price (Hunt, 2001). This is 50 \$/year or 0.3 \$/ha. The real interest rate is 3.5%, based on a 14% inflation rate and an 18% investment rate. The interest cost of the machine is 70 \$ per year or 0.46 \$/ha, as shown in Eq. (7).

| Table 7. *Total Costs of the Machine* | |
|---|---|
| **Cost Type** | **Value (\$/ha)** |
| Repair and maintenance | 1.6 |
| Depreciation | 1.33 |
| Interest | 0.3 |
| Shelter, taxes, and insurance | 0.46 |
| Tractor cost | 3.57 |
| Total cost | 7.26 |

$$2000\left(\frac{\$}{year}\right)\times 0.035=70\left(\frac{\$}{year}\right) \quad (7)$$

The R & M cost of the concept is 0.4 \$/h or 1.6 \$/ha, based on the average purchase price for harvesters 0.02% (Hunt, 2001). The total machine cost is 7.26 \$/ha (see Table 7), which includes 15 \$/day or 3.57 \$/ha for a rented tractor (with operator and fuel costs). The cost of collecting the crop from the field by laborers is not included.

The concept has some important features, such as acceptable field capacity, losses, and reliability (Table 8). The equipment is affordable and cost-effective for the target area. The header can adapt to the ground unevenness and harvest low plants, which improves the mechanization of chickpea harvesting. The new method and machine for chickpea harvesting are efficient, with good maneuverability, low operating costs, a reasonable purchase price, and a work rate of 0.42 ha/h.

## Discussion

Mennad et al. (2017) examined the effect of weather conditions, varieties, and harvesting modes on the yield of lentil in Algeria. It shows that the rainfall distribution was unfavorable for crop development, but the temperature was suitable. The varieties differed in their height, maturity, and adaptability to mechanical harvesting. The mechanical harvesting caused more loss than manual harvesting, especially for short and early varieties. The Metropole variety was the most suitable for mechanical harvesting, while the Syrie 229 variety had the highest yield in manual harvesting. The overall yield and production potential of lentil were low in both campaigns. They concluded that 1) the current varieties and harvesting methods are not encouraging for lentil cultivation, 2) there is a need to design a new mechanical harvesting method or to improve the varieties through genetic methods, and 3) the focus should be on creating rigid and uniform varieties that can resist pod shattering and adapt to mechanized harvesting. Therefore, there is a mutual interest between the findings of the recent paper and the results of the current research, where it emphasizes that the total harvesting loss is more than that for the manually harvested condition, and

| Table 8. *Performance Factors of the Fabricated Chickpea Harvester Compared to Those in Manual and Mechanized Harvesting* | | | | | |
|---|---|---|---|---|---|
| **Performance Harvesting System (Year)** | **Field Capacity (ha/h)** | **Reliability (%)** | **Losses (%)** | **Purchase Price (\$)** | **Cost (\$/ha)** |
| Chickpea harvester | 0.42 | 66 | 20–28 | 2000 | 7.26 |
| Manually harvesting* | 0.015 | - | ≤5 | - | 80 |
| *Addressed by Golpira (2015). | | | | | |

shortfall and plant circumstances have affected the machine's ability.

Gharakhani et al. (2017) optimized a harvester for lentil plants where they tested three factors: forward speed, blades speed, and carousel speed. They found that forward speed was the most important factor and suggested the best settings for the harvester. They also compared the new cutter-bar of the harvester with a conventional one on different farms and found that the new one was more durable. However, they have not specified quantitative results regarding the actual harvesting losses. Tang et al. (2017) designed and tested a multi-functional rice combine harvester that can harvest grain and bale straw. This harvester could reduce environmental pollution, energy consumption, and labor cost. The study determined the optimal parameters and speeds for the threshing cylinder and the baler. The study also conducted field trials and measured the size, mass, and density of the straw bales. The harvester could be used for other stem crops as well. Modather et al. (2018) presented a paper that compares two types of combine harvesters for rice in Malaysia. It uses field and literature data to show that the mid-size harvester had better quality, less loss, and more suitability than the conventional harvester, which was imported and designed for wheat. It suggests that new harvesting methods or improved varieties are needed for rice cultivation in Malaysia, confirming the scope of this research, which is conducted to develop a specified harvester for chickpea based on the crop's requirements.

Another study tested the pod shattering resistance and the harvest delay limit in soybean where 16 soybean genotypes were planted and simulated the harvest delay on pots. They measured the pod shattering and seed dispersal on different nodes of the stem. The findings reveal that the lower nodes had more pods and more shattering than the upper nodes. They also classified the genotypes into five categories based on their resistance and suggested that resistant genotypes could be harvested 20 days after maturity, while susceptible genotypes should be harvested within three days (Krisnawati et al., 2022).

Wang et al. (2021) presented a review paper on the mechanized harvesting of rapeseed, which is very similar to chickpea in terms of its harvesting problems. They summarize the previous research on the structure, vibration, and control of the header, and suggest some future directions for improvement, such as 1) designing different types of vertical cutters to reduce vibration, cost, and weight, 2) improving the follow-up control of the vertical cutter to keep it perpendicular to the ground, 3) analyzing the overall vibration of the header and optimizing the configuration of its components, 4) studying the cutting characteristics of entwined branches of rapeseed and designing better cutters and reels, 5) combining agricultural machinery and agronomy to adjust the planting pattern of rapeseed and avoid pod burst loss. Their listed proposed key points and some other concerns, like economical concerns and average accessible power, encouraged the authors to conduct the current research.

## Conclusion

This research presents a new concept of a harvester for chickpea pods. The paper describes the design and evaluation of the harvester, which is tractor-pulled and has a platform, a reel, a power transmission system, and tire wheels. The paper aims to improve the harvesting quality and efficiency of chickpea, which is a sensitive and important crop in developing countries. The paper reports the following findings: 1) the harvester has a reliability of 66%, which is acceptable for a concept machine and can be improved by reducing downtimes and increasing forward speed. 2) The harvester has a field capacity of 0.42 ha/h, which is 16.6 times faster than manual harvesting and can harvest 150 hectares in a year. 3) The harvester has a total loss of 20% of the yield, which is good for a concept machine and can be achieved by adjusting the reel kinematic index to 2.4, the forward speed to 3 km/h, and the reel speed to 55 rpm. 4) The harvester produces cleaner and healthier grain compared to the case where it is harvested by labor, which is important for the market and the consumers. 5) The harvester has a low operating cost of 7.26 $/ha, which includes the cost of depreciation, shelter, insurance, taxes, interest, repair and maintenance, and tractor rental. The paper concludes that the new concept of the chickpea harvester is efficient, cost-effective, and suitable for the target area. The paper suggests that the concept can be further improved by designing a pneumatic conveyor for material handling, modifying the reel to avoid pod shattering, and searching for new varieties that are better adapted to mechanical harvesting. The paper also acknowledges the limitations of the study, such as the low number of replications, the dry year in the study area, and the exclusion of labor costs for collecting the crop from the field.

The study concludes the following:

1) There is a need for more research and innovation on the mechanization of chickpea harvesting, as it can increase the yield and production potential of chickpeas.
2) The focus should be on creating harvesters that can adapt to the ground unevenness, harvest low plants, avoid pod shattering, and produce cleaner and healthier grain.
3) The harvesters should also be compatible with the crop characteristics, such as the height, maturity, and shattering resistance of chickpea varieties.

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