Economics of using combine harvesters in the mechanized rainfed schemes of eastern Sudan

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ABSTRACT

The effective use of combine harvesters not only needs knowledge about operation requirements, but also needs economic evaluation. The objective of this study was to make economic analysis for combine harvesters used in harvesting mechanized rainfed schemes in eastern Sudan. The data were collected from combine harvesters owners through a comprehensive questionnaire that covered 23 combine harvesters in 2016/2017 season. The collected data included fixed cost items such as purchase price, insurance, shelter and taxes and variable cost items like repair and maintenance, fuel, oil, drivers and supervision. Also, data on harvester working parameters like annual harvested area and working hours, besides custom hiring price and crop yield, were collected. In addition to cost analysis, the breakeven point (BEP), in terms of hectares that have to be harvested annually to cover annual fixed costs; and the payback period (PBP) were calculated. Also, sensitivity analyses were carried out to detect the effect of changing cost parameters on BEP and PBP. The results indicated that the annual harvested area by a combine harvester was found to be 1525 ha in 623 hours. The average fixed cost was found to be 207.5 SDG/ha, which constituted about 16.8% and 68.5% of the purchase price and total operating cost, respectively. Whereas the average variable cost was 95.4 SDG/ha, representing 7.7% and 31.5% of the purchase price and total operating cost, respectively. The results indicated that the depreciation cost was the highest among the fixed cost items and fuel cost was the highest among the variable cost items. The results showed that the average cost for direct harvesting operation was 303 SDG/ha (742.1 SDG/hr). It was found that the BEP was 904 ha and the PBP was 9 years. The sensitivity analysis revealed that increasing the purchase price will increase both the BEP and PBP. The study concluded that the use of a combine harvester in the mechanized rainfed schemes for direct harvesting was profitable for both farmer and investor. When the annual required areas by the combine harvester was satisfied, the estimated profit was 143 SDG/ha. However,it is not advisable to use direct harvesting when crop yield is lower than 450 kg/ha.

INTRODUCTION

Harvesting of field crops is one of the most important farming operations. It could be categorized into three systems; fully manual, semi-mechanized and fully mechanized (direct combining) harvesting systems. Due to the shortage of the hand labor, combine harvesters play a central role in harvesting field crops, as they provide timely harvest and maintain good grain quality. Many factors govern the success of direct harvesting of field crops by a combine harvester such as crop features, weather and soil conditions, readiness and management of the combine harvester, as well as economic aspects.

Farm machinery cost represents a high proportion of the total farm cost (Anderson, 1988; Buckmaster, 2003). Machinery cost includes fixed and variable costs, which form total machine cost (Kepner, *et al.*, 1982; Hunt, 2001; William, 2005). Fixed cost occurs regardless of the machine use, while the operating cost varies with the machine use as well as penalties for lack of timeliness. Fixed costs include depreciation, taxes, insurance, interest on investment and shelter costs. Variable costs include repair and maintenance, fuel, oil, labor as well as supervision costs. Supervision costs are those expenses related to the provision of a car with a technician to follow, serve and manage the combine harvester. Fixed, variable, and total machine costs can be calculated on an annual, hourly, or per unit area basis. Burton (2005) indicated that fixed costs per unit area vary inversely with the amount of annual use of a machine. It is well known that the combine harvester is characterized by seasonal work in only a few weeks or months per year. Therefore, a certain minimum amount of work must be available to justify the purchase of a combine harvester.

Tahir, *et al.*(2003) mentioned that the combine harvester is an efficient, economical, labor and time saving machine but its initial cost is quite high. Moreover, the fixed cost of the combine harvester is the greatest machinery cost, comprising 40% of the harvest total cost (Isaac, *et al*., 2006). For economic efficiency, Spokas and Steponavicius (2011) advised that a combine harvester has to provide the highest possible performance with the lowest possible operating costs.

The cost of operating a combine harvester varies from one country to another according to purchase price, age, work rate and annual use, as well as local prices of fuel, oil, spare parts and labor wages. Several studies worldwide have estimated harvesting cost for a variety of harvesting methods with different scenarios and calculation procedure (Sharanakumar, *et al.*, 2011; Soucek and Blazej, 2012; Yousif and El-Awad, 2012; Hossain, *et al.*, 2015; Masek,*et al.*, 2015). In fact, investment on a combine harvester requires large fund, which affects benefit cost ratio, and hence farm profitability in the long-run.

In the commercial mechanized rainfed schemes of Gedarif State in eastern Sudan, direct combine harvesting of grain crops like sorghum, pearl millet and sunfloweris necessary due to vast cropped areas coupled with the shortage of hand labor during harvesting period. Combine harvesters are recently introduced to replace the conventional harvesting systems by using hand cutting with sickles and stationary threshing. Many inquiries wereraised about the economics of using combine harvesters in the region; unfortunately, the available information is inadequate. Therefore, providing of information on costs, net return, breakeven point (BEP) and pay-back-period (PBP) of combine harvesters is of great necessity for their successful operation and sustainable use.

This study was carried out to perform economic analysis for combine harvesters used in direct harvesting in the mechanized rainfed schemes of eastern Sudan.

MATERIALS AND METHODS

Gedarif State lies in the eastern part of the clay plain of the Sudan, and is famous for big mechanized schemes. About 3 million hectares are cultivated annually. According to the farm size, the rainfed area is divided into two main sectors, which are the traditional and the mechanized sectors. In the traditional sector, the farm size ranges between 2.1 and 210 ha; which are considered as subsistence farms for smallholder farmers with a limited use of machinery. The mechanized sector consists of large commercial schemes 420 ha and more in size; in which different sets of machinery are used. These commercial schemes are cultivated and managed by private farmers. Sorghum is the dominant crop grown. Semi mechanized harvesting of sorghum by hand cutting and stationary mechanical threshing is the dominant practice. The cost of the mechanical threshing in season 2016/2017was 457 SDG/ha including the cost of labor for bagging and handling the harvested grain. Roughly, about 70 combine harvesters of different makes and models are working in the large commercial schemes. The combine harvester either works for 9 or 18 hrs per day depending on availability of drivers. For example, in the former case, the combine has one driver works for dayshift, while in the later case two drivers work for day and night shifts. Every driver is accompanied by an assistant.

A comprehensive questionnaire was designed and used to collect the required data. The collected data were restricted to direct combine harvesting of sorghum in the large commercial schemes. Data from 23 combine harvesters were collected from farmers and machine owners during 2016/2017 season. The studied combine harvesters were New Holland (5070, 5060 and 5.8) and Claas (Avero 240). The age of the studied harvesters ranged between 1 and 7 years. Data on purchase price, insurance, shelter and taxes costs were collected and used to calculate the fixed cost. For variable cost calculation, the data on repair and maintenance, fuel, oil, labors and supervision costs were collected. Moreover, other data on machine working parameters such as annual harvested area, annual working hours, work rate, and custom hiring price as well as crop yield were collected. Furthermore, inflation rate and investment rate were taken from Bank of Sudan records.

Fixed and variable costs as well as total operating cost items were calculated as percentages of purchase prices, per unit area and per hour of use. Moreover, breakeven points (BEP) in terms of number of hectares that have to be harvested annually to cover annual fixed costs was determined. Furthermore, payback period (PBP), i. e., number of working years by the combine harvester required to return back its initial cost was calculated. Besides that, sensitivity analyses were carried out to detect the effect of changing combine harvester cost parameters on BEP and PBP. For sensitivity analyses, changes in purchase price (fixed cost) were used against changes in both variable cost and custom hiring price to determine the changes in BEP. Changes in purchase price were also used against the changes in both total variable cost and total income to determine the changes in PBP. For achieving sensitivity analyses, the purchase price was changed by 15%, 30% and 45% above and below the average purchase price; at the same time, the other variables such as fixed costs, variable costs, custom hiring price and total income were changed by the same rates.

The studied combine harvesters were sufficient and representative of the existing combines in the region. The collected data was inserted in an excel worksheet and simple descriptive statistical analysis was used.

RESULTS AND DISCUSSION

Table 1 shows the average working parameters and purchase price of the studied combine harvesters. The results revealed that a combine harvester, on the average, can harvest 1525 ha in 623 hours annually at work rate of 2.45 ha/hr. The obtained annual working hours are reasonable as the harvesting period extends from November to February, and the soil and weather conditions are suitable for the combine workability. Beside that, the machines working in large schemes means less unproductive time. For these reasons and coupled with the combine output per hour, the obtained result on annual harvested area is achievable. Consequently, the combine harvester economics could be considered valid.

On the other hand, the studied combine harvesters worked in schemes of an average sorghum grain yield of 764.5 kg/ha (Table 1), which is below the world's average. However, an increase in grain yield is expected in the coming years because farmers start to adopt and use the improved production technologies. Based on the combine harvester work rate and the sorghum yield, the average output of the combine was about 1.87 ton/hr.

Table 1. Average working parameters and purchase price of combine harvester.

Parameter	Symbol	Value
Work rate (ha/hr)	WR	2.45
Annual working hours (h/yr)	Hs	623.0
Annual harvested area (ha/yr)	A	1525.0
Yield (kg/ha)	Y	764.5
Purchase price (SDG)	PP	1888893

Table 2 displays the average annual fixed, variable and total operating costs as percentages of purchase price (SDG/ha and SDG/hr). The results indicated that the average annual fixed, variable and total operating costs constituted 16.7%, 7.7% and 24.4% of the purchase price of combine harvester, respectively. According to the current situation, the cost calculation of a combine harvester revealed that the average fixed cost was 207.5 SDG/ha and 508.7 SDG/hr. Also, the calculation indicated that the average variable cost was 95.4 SDG/ha and 233.4 SDG/hr. Consequently, the total combine harvesting costs per unit area and unit time (hour) were 302.9 SDG/ha and 742.1 SDG/hr, respectively. Moreover, Table 2 indicates the percentage and value of each cost item. Judgment on the expense of these costs is difficult as there is no previous data available for these costs. Therefore, the furnished information can help farmers, investors and researchers to be aware of combine harvester costs for direct harvesting in the mechanized rainfed schemes.

Table 2. Costs of combine harvester.

	% of PP	SDG/ha	SDG/hr
Fixed cost			
Depreciation	9.0	111.4	273.0
Interest	6.6	81.7	200.2
Insurance	0.5	6.3	15.5
Shelter	0.3	4.1	10.1
Tax	0.3	4.0	9.9
Total fixed cost	16.7	207.5	508.7
Variable cost repair and maintenance	2.0	25.3	61.9
Labor cost	1.7	20.6	50.3
Fuel cost	2.8	34.4	84.2
Oil cost	0.5	6.1	14.9
Supervision	0.7	9.0	22.1
Total variable cost	7.7	95.4	233.4
Total operating cost	24.4	302.9	742.1

Fixed cost items of combine harvester were determined as a percentage of total fixed cost and as a percentage of total operating cost (Fig. 1). As a percentage of total fixed cost, depreciation represented the highest fixed cost (54%) followed by interest (39%), whereas insurance (3%), shelter (2%) and taxes (2%) comprised the lowest percentage of fixed cost (Fig.1). However, these cost items showed the same trend as a percentage of total operating cost. The depreciation, interest, insurance, shelter and taxes constituted 36.8%, 27.0%, 2.1%, 1.4% and 1.3% of the total operation cost, respectively. The total fixed cost of a combine harvester amounted to 68.5% of the total operating cost; and this result agrees with the findings of Isaac, *et al*., (2006)who stated that the fixed cost was the greatest component of the total combine harvester cost.

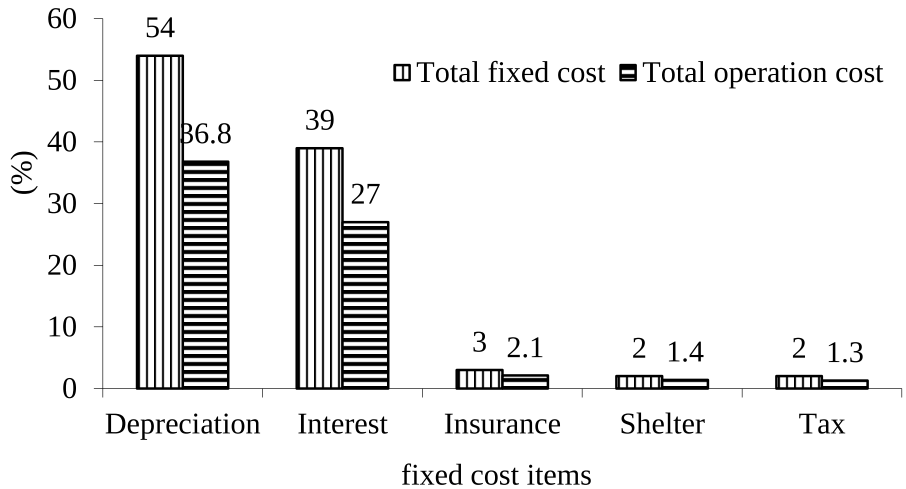

Fig.1. Percentage of fixed cost items of combine harvesters from total fixed and total operation costs

The variable cost items of the combine harvesters were determined as a percentage of total variable cost and as percentage of the total operating cost (Fig. 2). As a percentage of total variable cost, fuel cost represented the highest variable cost (36%) followed by repair and maintenance cost (27%) and labor cost (22%); whereas, supervision and oil costs constituted the lowest percentage of variable cost (Fig. 2). On the other hand, these cost items showed the same trend as percentages of the total operating cost. The cost of fuel, repair and maintenance, labor, supervision and oil constituted 11%, 8%, 7%, 3% and 2% of total operating cost, respectively. However, Spokas and Steponavicius (2011) found a very high influence of fuel consumption on the total combine harvester operating cost. The total variable cost of a combine harvester amounted to 31.5% of the total operating cost.

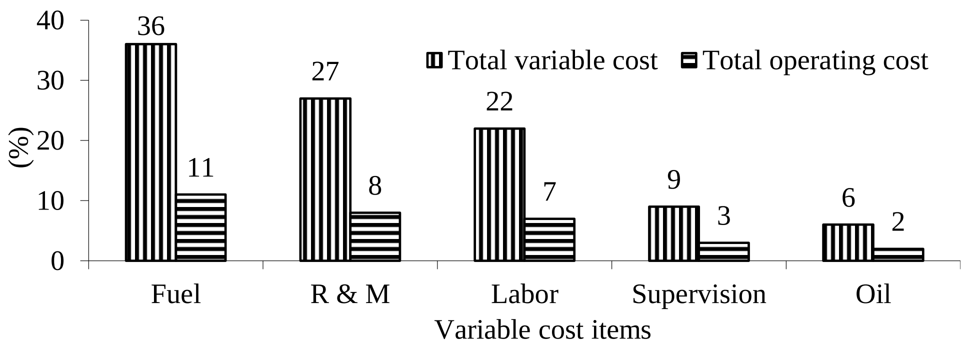

Fig.2. Percentage of variable cost items of combine harvesters from total operating cost and total variable costs

The economic analysis of combine harvesters' performance revealed that the total annual income was greater than the total annual operation cost, and the annual net return was found to be 218571 SDG (Table 3). This indicates the profitability of possessing and operating a combine harvester for direct harvesting of crops in large commercial schemes of the Sudan. The results showed that direct harvesting by owning a combine harvester was cheaper than the direct harvesting by custom hiring of the service; as they cost 303 SDG/ha (Table 2) and 446 SDG/ha (Table 3), respectively.

On the other hand, the results showed that the calculated upper yield limit to economically operate a combine harvester in a farm was 450.0 kg/ha (Table 3). This means that the operation of the studied combine harvesters is economically safe as they work in farms having average grain yield of 765 kg/ha (Table 1). Therefore, it is not advisable to harvest sorghum farms by direct combining when the expected yield is below the upper yield limit. However, higher sorghum grain yields may affect the combine performance, and hence the operation costs. In higher yield fields, the driver has to slow down forward speed of the combine harvester to avoid congestion of crop materials inside the harvester and to avoid sorghum heads shattering. Moreover, higher yield leads to loss of time due to frequent stopping to unload the grain tank. Therefore, grain yield affects the cost of direct combine harvesting operation.

The results showed that the average breakeven point (BEP) of a combine harvester was 904 ha. This means that the combine harvester has to harvest annually such an area to cover its annual fixed cost. When comparing the BEP with the annual harvested area of 1525 ha (Table 1)it was found that the cost of 41% of the annually harvested area was just the variable cost. This result indicates that as the annual harvested area increased beyond the BEP, the more net return will be gained from the investment on a combine harvester.

The results, also, revealed that the average payback period (PBP) of a combine harvester was 9 years (Table 3). This was mainly due to the high purchase price of the combine harvester. However, it is possible for a combine harvester to reduce that period if properly managed. In the studied area, the combine harvester is under the warranty of the dealer during the first year of purchase, and it was observed that there were no major breakdowns in its components during the first five years. On the other hand, there is the possibility of increasing the net return from the combine harvester, hence, reducing the payback period; and this can be achieved by extending its harvesting season through its use in nearby-irrigated schemes (New Halfa and Rahad Schemes) for harvesting wheat and sunflower crops during March to May.

Table 3. Economic analysis of combine harvester.

Parameter	Symbol	Calculation procedure	Value
Annual fixed cost (SDG/yr)	FC	= Average value	316804.0
Annual variable cost (SDG/yr)	VC	= Average value	45337.0
Total cost (SDG/yr)	TC	= FC+ VC	2141.0
Custom hiring price (SDG/ha)	CHP	= Average value	446.0
Total income (SDG/yr)	TI	= CHP x A	680712.0
Net return (SDG/yr)	NR	= TI-TC	8571.0
Yield limit (kg/ha)	YL	= (FC/A)/{(CHP VC_a)/Y}	450
Breakeven point (ha)	BEP	= FC/(CHP - VC_a)	904.0
Payback period (yr)	PBP	= PP/NR	9.0

VC_a = Variable cost (SDG/ha), PP = Purchase price (SDG).

Sensitivity analysis

The sensitivity analysis was done to explore the effect of changing some economic variables on BEP (ha) and PBP (years). Table 4 shows the effect of changing combine harvester purchase price, hence, fixed cost on one side and variable cost and custom hiring price on the other side on BEP. The results showed that, on the average, 904 ha can cover the annual fixed cost of the combine harvester under the present conditions. The minimum BEP was 343 ha was obtained by decreasing the purchase price by 45% and increasing both variable cost and custom hiring price by 45%. The highest BEP was 2382 ha which was obtained by increasing the purchase price by 45% and decreasing both variable cost and custom hiring price by 45%. If the purchase price was increased by 15%, 30% and 45% from the average price and no change in the variable cost and custom hiring, the expected BEP was 1039, 1175 and 1310 ha, respectively. Many scenarios can be made from Table 4. From these scenarios it is noticeable that the purchase price has immense effect on the BEP rather than the custom hiring price and variable cost.

Table 4. Effect of changing combine harvester cost parameters on breakeven point (BEP), ha.

Changes in variable cost and custom hiring(%)	Changes in purchase price (fixed cost) (%)						
	-45	-30	-15	Average	+15	+30	+45
-45	904	1150	1396	1643	1889	2136	2382
-30	710	904	1097	1291	1484	1678	1872
-15	585	744	904	1063	1223	1382	1541
Average	497	633	768	904	1039	1175	1310
+15	432	550	668	786	904	1021	1139
+30	382	487	591	695	799	904	1008
+45	343	436	530	623	717	810	904

Table 5 shows the effect of changing combine harvester purchase price, from one side and total operating cost (fixed plus variable costs) and total income from the other side on the PBP, which is the minimum years that can cover the purchase price of the combine harvester. The results showed that the average of 9 years are quite enough to payback the original cash invested in a combine harvester under the present conditions. The maximum PBP was calculated to be 208 years, which was obtained by increasing purchase price by 15% and decreasing fixed, variable costs and total income by 30% (Table 5). If the purchase price was increased by 15%, 30% and 45% from the current average price and no change in the fixed, variable cost and total income, then the expected PBP was 13, 20 and 36 years, respectively (Table 5). Many scenarios can be made from Table 5. From these scenarios it is noticeable that the purchase price has a major effect on the PBP.

Table 5. Effect of changing combine harvester cost parameters on payback period (PBP), years.

Change in fixed and variable costs and total income(%)	Changes in purchase price(%)						
	-45	-30	-15	Average	+15	+30	+45
-45	9	18	64	-85	-97	-21	-17
-30	5	9	15	33	208	-66	-32
-15	4	6	9	14	24	57	-637
Average	3	4	6	9	13	20	36
+15	2	3	5	6	9	12	18
+30	2	4	4	5	7	9	12
+45	2	2	3	4	5	7	9

CONCLUSIONS

1. The annual average harvested area by a combine harvester was found to be 1525 ha in 623 hours.
2. The average fixed cost of the studied combine harvester was 207.5 SDG/ha constituting 16.8% and 68.5% of the purchase price and operating cost, respectively.
3. The variable cost was 95.4 SDG/ha comprising 7.7% and 31.5% of the purchase price and operating cost, respectively.
4. Fuel cost represents the highest share of the combine harvester variable cost.
5. The total operation cost was 303 SDG/ha and 742.1 SDG/hr.
6. The upper yield limit to operate combine harvester economically in a farm was found to be 450 kg/ha.
7. For the studied combine harvesters the average BEP was904 hectares and the PBP was 9 years.
8. The sensitivity analysis revealed that the purchase price has the major effect on the BEP and PBP.
9. The use of a combine harvester under the current conditions in the mechanized rainfed schemes for direct harvesting was profitable for either farmers or investors. When the annual required areas by the combine harvester was satisfied, the estimated profit was 143 SDG/ha.
10. It is not advisable to use direct harvesting when crop yield is lower than 450 kg/ha.

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اقتصاديات استخدام الحاصدة المركبة في مشاريع الزراعة الآلية المطرية بشرق السودان

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الخلاصة

إن الاستخدام الفعال للحاصدة المركبة لا يحتاج لمعرفة فنية تختص بمتطلبات التشغيل فقط وإنما يحتاج أيضا لمعلومات اقتصادية. الهدف من هذه الدراسة هو إجراء تحليل اقتصادي للحاصدات المركبة المستخدمة لحصاد مشاريع الزراعة الآلية المطرية بشرق السودان. جمعت البيانات من أصحاب الحاصدات عن طريق استبيان شامل، لعدد 23 حاصدة في موسم 2017/2016م. البيانات التي جمعت تشمل عناصر التكاليف الثابتة مثل سعر الشراء والتأمين والتخزين والضرائب وعناصر التكاليف المتغيرة مثل الصيانة والإصلاح والوقود والزيوت والسائق والإشراف. أيضا جمعت بيانات عن عوامل تشغيل الحاصدة مثل المساحة المحصودة وعدد ساعات التشغيل السنوية، بجانب سعر الإيجار والإنتاجية. إضافة لتحليل التكاليف تم حساب كل من نقطة التعادل (BEP) بمعنى عدد الهكتارات التي يجب حصادها سنويا لتغطية التكاليف السنوية الثابتة، وفترة استرداد سعر الشراء (PBP). كما تم إجراء تحليل الحساسية لمعرفة أثر تغيير بنود التكاليف على نقطة التعادل وفترة استرداد سعر الشراء. أظهرت النتائج أن الحاصدة المركبة في المتوسط تحصد 1525 هكتار سنويا خلال 623 ساعة. كان متوسط التكلفة الثابتة 207.5 جنيه/ الهكتار وهي تشكل 16.8% و 68.5% من سعر الشراء وتكاليف التشغيل الكلية على التوالي. بينما كان متوسط التكلفة المتغيرة 95.4 جنيه/الهكتار وهي تمثل 7.7% و31.5% من سعر الشراء وتكاليف التشغيل الكلية على التوالي. أشارت النتائج أن الإهلاك كان أكبر التكاليف ضمن عناصر التكاليف الثابتة وتكلفة الوقود كان أكبر التكاليف ضمن عناصر التكاليف المتغيرة. أشارت النتائج إلى أن متوسط تكلفة الحصاد المباشر كانت 303 جنيه/الهكتار والتي تعادل 742.1 جنيه/الساعة. وجد أن نقطة التعادل تساوي 904 هكتار وأن فترة استرداد سعر الشراء كانت 9 سنوات. أشار تحليل الحساسية إلى أن زيادة سعر الشراء يؤدي لزيادة كل من نقطة التعادل و فترة استرداد سعر الشراء. خلصت الدراسة إلى أن استخدام الحاصدة المركبة تحت الظروف الحالية في مشاريع الزراعة الآلية المطرية للحصاد الآلي المباشر مربح لكل من المزارعين أو المستثمرين إذا ما توفرت المساحات المطلوبة سنويا للحاصد. ويقدر الربح بواقع 143 جنيه/الهكتار. لكن لا ينصح باستخدام الحصاد الآلي المباشر إذا قلت الإنتاجية عن 450 كجم/الهكتار.