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Mechanical Harvesting Losses in Rice Crop using Combin. Harvester

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ABSTRACT

An evaluation was carried out using Kubota Combine (Pro 481) as a mechanical harvester of rice (Sakha 102). The grain moisture content was varied at (23.8, 19.3 and 6.5%). Forward speeds were (2.3.27,4.5 and 5.14 km/h) and air fan velocities (22.2,25.3, and 27.6). The were previous factors studied and evaluated on combine losses (as header, threshing, separating and shoe losses). The field experiments were carried out at Hammour village, Damanhor, Behara Governorate, Egypt (قرية حمور البحيرة), during agricultural seasons of 1999-2000 and 2000-2001.

The main objectives of this study were to determine the optimum operating conditions as time of harvest, forward speed and air fan velocity for adjusting the combine machine in order to obtain the minimum losses.

The results show that:

- Header, threshing, separating and shoe losses increase with increasing of the forward speed and the decrease of grain moisture content.
- The shoe losses increase (From 0.24 to 1.05%) with the increase of air fan velocity (from 6.17 to 7.67 m/s).
- The total loss "TL", forward speed "S" and grain moisture content "GMC" were formulated by the formula "$TL = (10.5\ GMC^{-0.79})\ S^{0.76}$ (under previously mentioned condition).
- The optimum operating harvesting rice crop was at combine forward speed 4.5 km/h and grain moisture content of 16.5%.
- The optimum air fan velocity during operating harvesting rice was 6.17 m/s.

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1. INTRODUCTION

Rice crop is one of the major field crops in Egypt. It is grown in 1.3 million feddan of the total agricultural area. During the five years before 2000 paddy production averaged 4.6 million tons and the national average yield was 3.6 tons/fed., Ministry of Agriculture (2000) A.R.E.

Mechanical harvesting is one of the most. important operations in rice crop production.. Government encourages the farmers to use new technology to overcome the high cost of traditional harvesting and labour shortage especially in the harvesting time. Therefore it is necessary to mechanize rice harvesting to reduce losses and costs. Combine harvester should be used for its minimum production losses and low cost.

Awady *et al.* (1982) conducted a critical comparison between wheat combine harvesters under Egyptian condition. They found that the high percentage of seed damage resulted from high grain moisture contents. **Sheruddin *et al.* (1991)** found that with decreasing moisture content of grain, increased grain losses. The lowest grain losses were observed at a range of 4 – 15 (W.b.) grain losses increased with dalay in harvesting and at different timings of harvest. **Kepner *et al. (1982)*** found that seed losses from a combine can occur in connection with any of the four basic operations. These losses are often identified as header, cylinder, walker and shoe losses. Gathering losses in direct combining include heads, pods, or ears, and free seed, lost during the cutting and conveying operations. They stated that threshing effectiveness is related to: cylinder speed, cylinder concave clearance, number of rows concave teeth used with spike tooth cylinder type of crop, the condition of crop in terms of moisture content, maturity etc., and the rate at which the material is fed into the madnine. **Wang *et al.* (1988)** illustrated that at harvesting barley and wheat, the separation loss was less than 1% for the test combine at material other than grain feed rates below 8 t/h. However when the feederate increased to a certain level the loss increased drastically. **Griffen (1976)** indicated that shoe losses may be caused by too much air from fan,

too much material on chaffer, and improperly adjusted chaffer and sieve. Helmy *et al.* (1995) indicated that increasing the forward speed tends to increase the actual field capacity and to decrease the field efficiency. They indicated also that the effective field capacity increased by decreasing straw moisture content.

The main objectives of this research are to study the factors affective on the mechanical harvesting losses in rice crop as:

1. Effect of combine forward speed on harvesting losses.
2. Effect of air fan velocity on shoe loss.
3. Effect of grain moisture content on harvesting losses.
4. Combine performance and harvesting costs.

3- MATERIALS AND METHODS

Combine, Kubota (PRO 481) was used for harvesting rice crop.

The field experiments were done in Hammour village, Damanhor, Behera Governorate, Egypt (قرية حمور البحيرة). A description of the material and methods of this study is presented in the following' sections,

3.1. MATERIALS:

3.1.1. The Combine harvester:

Kubota (PRO 481) combine is basically designed for rice and it is suitable also to use for harvesting other crops as wheat and barely.

Table (1): Specifications of combine harvester

Model		PRO 481
Overall width (with cutter), (mm)		1890
Traveling speed	forward	0 to 1.65
Traveling speed	backward	0 to 1.56
Blade width "mm"		1436

3.1.2 The crop:

The rice crop variety (Sakha 102) was used.

3.1.3 Instruments:

Some instruments were used to measure different parameters as:

- Grain moisture content device model (400PB – 70-22) limitation of measurement in rice : 6 to 24% .
- Air fan velocity device: range 0.2 to 40 m/sec.

- An electrical balance (digital) with an accuracy of 0.1 g.
- Stop watch, measuring scale.
- Several square wood frames.
- Long sheets of canvas.

3.2. METHODS:

3.2.1.Experimental procedure:

The experiment procedures were carried by combine harvester at three different grain moisture contents for rice (23.8, 19.3 and 16.5%), at different four forward speed averages (2, 3.27, 4.5 and 5.14 km/h) and at different three air fan velocity averages (6.17, 7.03 and 7.67 m/s) respectively. Every experimental treatment area was repeated three times. The total experimental area was three feddans (1.26 ha).

3.2.2. Grain losses:

3.2.2.1. Pre-harvesting losses measurement:

Pre-harvest losses were determined by locating a wooden frame of one square meter on the unharvested area and the grain fall on the ground inside the frame were collected and weighted. The percentage of preharvest losses was calculated by using the following equation:

$$\text{Pre-harvest loss} = \frac{\text{Pre - harvest loss}}{\text{Total yield}} \times 100$$

3.2.2.2. Header losses measurement:

The header loss was measured by locating a wooden frame of one square meter randomly in the harvesting tested area where the throughput of the combine was previously collected on the canvas-sheet. The grain losses in the frame were pre-harvest and header losses together. The pre-harvest losses must be subtracted.

3.2.2.3 Threshing losses measurement:

Threshing losses were determined by dragging two canvas sheets behinds the combine, one above other in appropriate positions. The collected materials on the top of canvas sheet consist of straw threshed grain and unthreshed grains.

The unthreshed ears were separated out from the grain threshed and straw, then threshed by the laboratory thresher. The grains were weighed.

3.2.2.4. Separating losses measurement:

The separating loss represent, the free grain discharged from the drum and rubbed into the top of canvas sheet for a distance of 5 meter under ken replicates.

3.2.2.5. Shoe (cleaning) losses measurement:

The lower canvas sheet collects the chaff and free grain from the cleaning device. The collected material from the lower canvas sheet was effected by air fan speed to get the free grain.

3.2.3. Grain moisture content measurement:

The moisture content was measured by using moisture content grain device.

3.2.4. Combine performance efficiency:

The performance efficiency of harvesting is obtained from measuring the machine output and the total losses.

$$\text{performance efficiency \%} = \frac{\text{Output}}{(\text{Output} + \text{Total losses})} \times 100$$

where:

The machine output is the amount of grain collected in the bin of the harvester.

Total losses are the whole losses of the combine [header, threshing, separating and shoe (cleaning) loss].

3.2.5. Criterion cost "C" :

The criterion cost of the harvesting operation was estimated by using the following equation (Awady *et al.*, 1982).

Cost of harvesting:

$$Mc = \frac{P}{H}\left(\frac{1}{L} + \frac{I}{2} + a + r\right) + (1.2w \times f \times u) + b$$

where:

Mc : Cost per hour of operation LE/h.

P : Estimated price of machine LE = (130000 LE).

h: Estimated yearly hours of operation, (h) = (600 h).

L : Life expectancy of the machine year = (10 years).

i : Annual interest rate. = (10%).

a: Annual taxes and overheads = (3%).

r: Annual repairs and maintenance rate = (7%).

1.2 : A correction factor for rated load ratio and lubrication = w : Engine power, hp was 48 hP

f: Specific fuel consumption (L/hp.h) = 0.3 kg/hp.h.

u: fuel price, L.E/L = (u/0.85) L.E/kg = (0.40L.E).

b: Hourly labour wage L.E/h = (5.5 L.E.).

Criterion cost (L.E/fed) = Operating cost (L.E/Fed) + Grain loss cost (L.E/fed).

Where:

$$\text{Operating cost (LE/Fed)} = \frac{\text{Machine cost, L.E / h}}{\text{Actual field capacity, Fed/h.}}$$

RESULTS AND DISCUSSION

4.1. Combine harvesting losses:

4.1.1. Header loss, "H_L":

The forward seed and grain moisture content had effect on header loss. Fig. (4.1) illustrates the header loss in rice crop versus forward speed at different moisture contents. The relationships between header losses "H_L" and forward speed "S" at different grain moisture contents "G.M.C." were fitted in the following equation:

$$H_L = a S^2 + bS + C \ldots\ldots\ldots (1)$$

where:

HL : Header loss (% of total yield).

S : Forward speed km/h and

a, b and c: Equation parameters.

Table (4.1): Relation between parameters a, b and c at different moisture content in rice crop.

G.M.C. %	A	b	c	R2%
23.8	0.03	-0.11	0.37	88
19.3	0.08	-0.43	1.15	84
16.5	0.048	-0.2	1.2	84
Mean	**0.053**	**-0.25**		

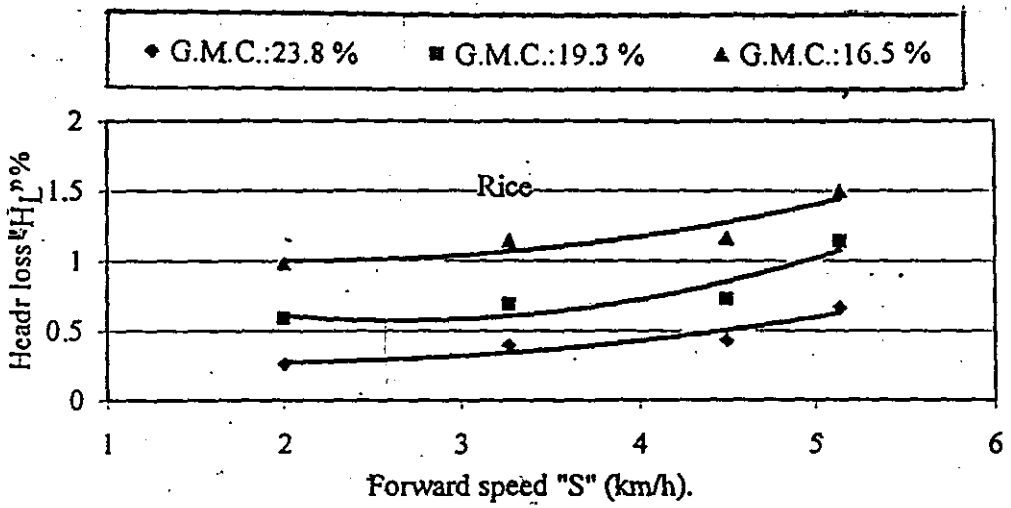

Fig. (4.1) : Relation between header losses (H_L) and forward speed (S) at different grain moisture content (G.M.C.) in rice crop.

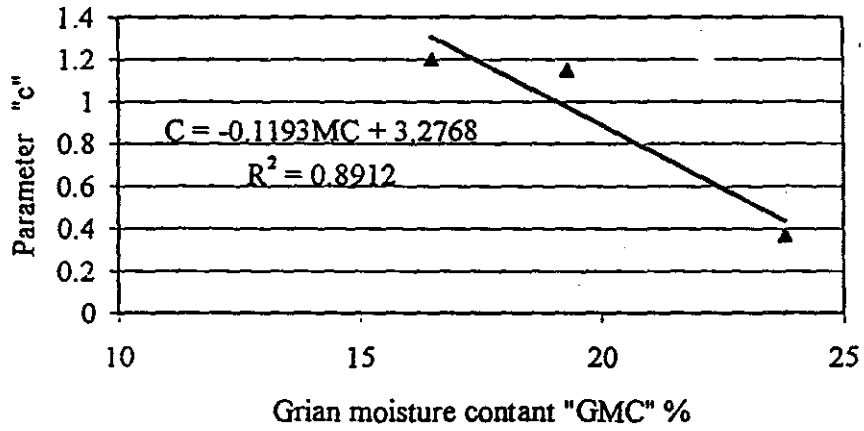

Fig. (4.2) : Relation between parameter "C" and grain moisture content (G.M.C.) header loss "H_L" in rice crop.

The parameter "C' depends on grain moisture content "G.M.C." as shown in Table (4.1) and Fig. (4.2), it was found that.

$$c = -0.119\ GMC + 3.3 \quad \ldots\ldots\ldots (2)$$

From equation (2) and (1), the general equation could be expressed as :

$$HL = -0.119\ GMC + 0.053\ S2 - 0.25\ S + 3.3 \quad \ldots\ldots\ldots (3)$$

4.1.2. Threshing loss "Th_l":

The forward speed and grain moisture content had effect on threshing loss. Fig. (4.3) shows the threshing loss in rice crop versus forward speed at different moisture contents.

The relationships between threshing loss "Th_L" and forward speed "S" at different grain moisture contents were fitted in the following equations:

$$Th_l = b\ S^a \quad \ldots\ldots\ldots (4)$$

where: "a" and "b" are equation parameters.

Fig. (4.4) illustrates the relation between parameters "a" and "b" and moisture content.

The relation between parameter "b" and moisture content "G.M.C." is:

$$b = (0.014\ GMC - 0.072) \quad \ldots\ldots\ldots (5)$$

From equations (4) and (5), the general equation could be expressed as :

$$Th_l = (0.014\ GMC - 0.072)\ S^{0.57} \quad \ldots\ldots\ldots (6)$$

4.1.3. Separating loss "Sp_L" :

The forward speed and rain moisture content had effect on separating loss. Fig. (4.5) shows the separating loss in rice crop versus forward speed at different moisture contents.

4.1.4. Shoe (cleaning) loss" Sh_L":

The forward speed, grain moisture content and air fan velocity had effects on shoe loss. Fig. (4.6 a, b, c, and d) illustrates the shoe loss in rice crop versus forward speed at different moisture contents and different air fan velocities,

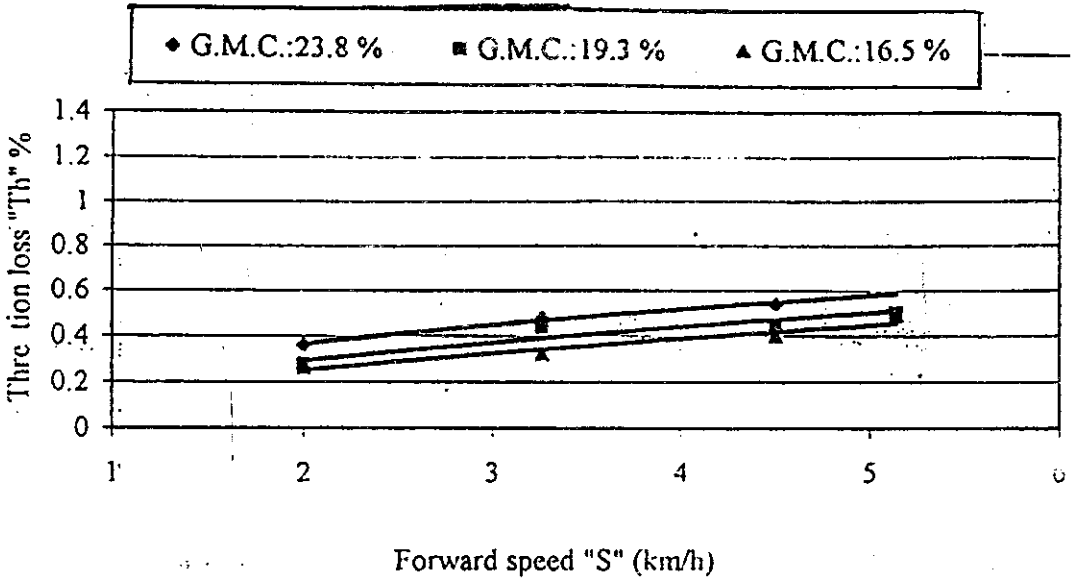

Fig. (4.3): Relation between threshing losses (T_{hl}) and forward speed (S) at different grain moisture content (G.M.C.)

$a = -0.018MC + 0.9312$ $\quad R2 = 0.9928$

$b = 0.0139MC - 0.0723$ $\quad R2 = 0.9913$

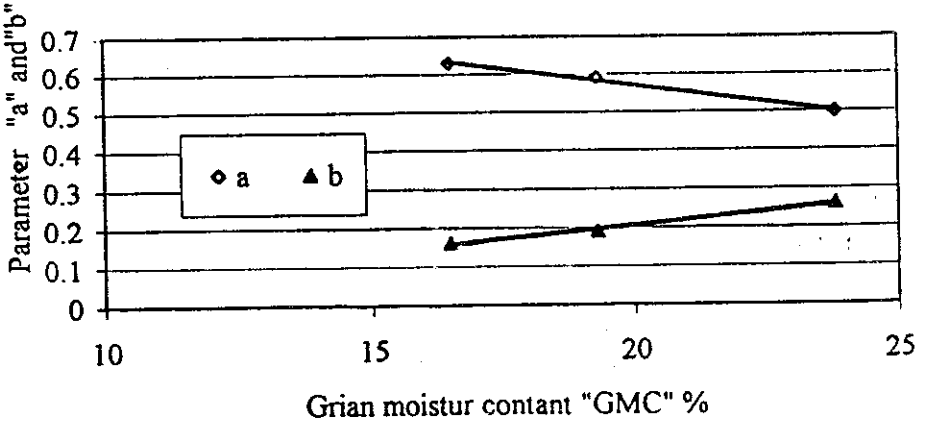

Fig. (4.4): Relation between parameters "a", "b" and grain moisture content (G.M.C.) threshing loss "T_{hl}" in rice crop.

4.1.5. Total losses "TL" :

Fig. (4.7) demonstrates the effect of forward speed and grain moisture content on the total losses of combine harvester. The relationships between total losses "TL" and forward speed "S" at different grain moisture content "G.M.C." were fitted in the following equations:

$$T_L = bS^a \quad \ldots\ldots\ldots\ldots (7)$$

where: "a" and "b" are equation parameters.

Table (4.2): Relation between parameters "a" and "b" with different moisture contents in rice crop.

GMCI%	A	b	R2%
23.8	0.77	0.89	
19.3	0.83	0.95	
16.5	0.7	1.2	
Mean	0.76		

Fig (4.8) illustrates the relation between parameter "b" and grain moisture content "G.M.C.".

The relation between parameter "b" and grain moisture content is:

$$b = 10.5\ GMC^{-0.79} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

From equations (7) and (8), the general equation could be expressed as :

$$T_L = 10.5\ GMC^{-0.79} . S^{0.76} \ldots\ldots\ldots\ldots (9)$$

4.2. Combine performance efficiency "Ce":

The combine performance efficiency is affected by the forward speed, grain moisture content and straw moisture content. The combine performance efficiency decreases with the increasing of the forward speed, at all different grain and straw moisture contents.

Figure (4.9) shows the effect of forward speed, grain moisture content and straw moisture content on the combine performance efficiency in harvesting rice crop.

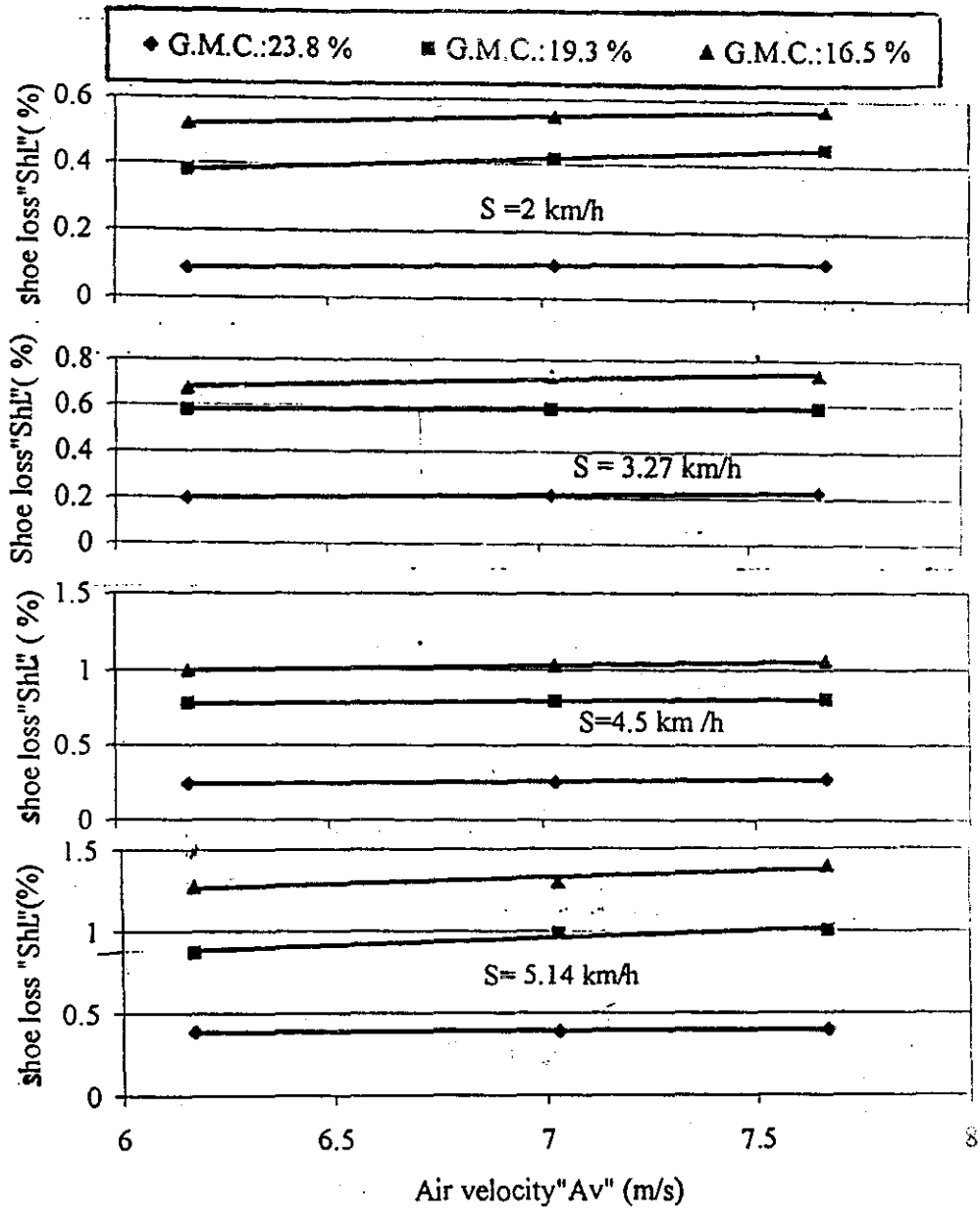

Fig. (4.6) : Relation between shoe losses "S_{hl}" and forward speed "S" at different grain moisture content "G.M.C." and different air fan velocity "A_V" in rice crop.

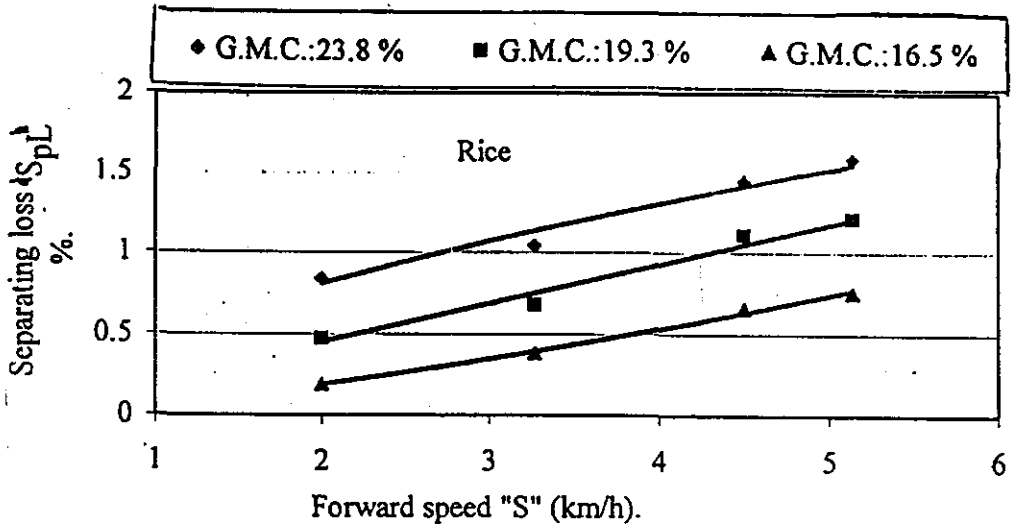

Fig. (4.5) : Relation between separating losses (S_{pl}) and forward speed (S) at different grain moisture content (G.M.c.) in rice crop.

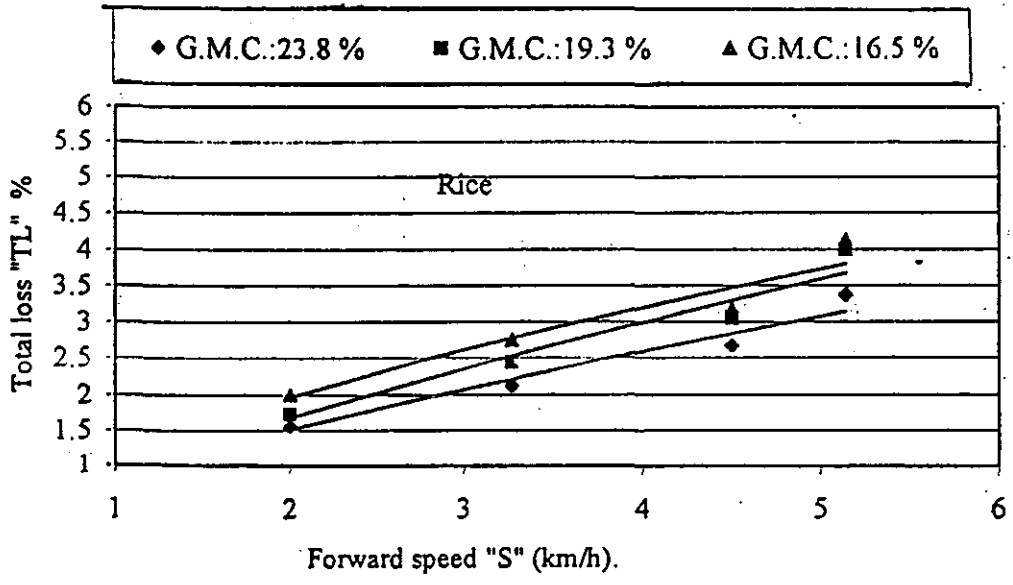

Fig. (4.7) : Relation between total losses "T_L" and forward speed "S" at different grain moisture content "G.M.C." in rice crop.

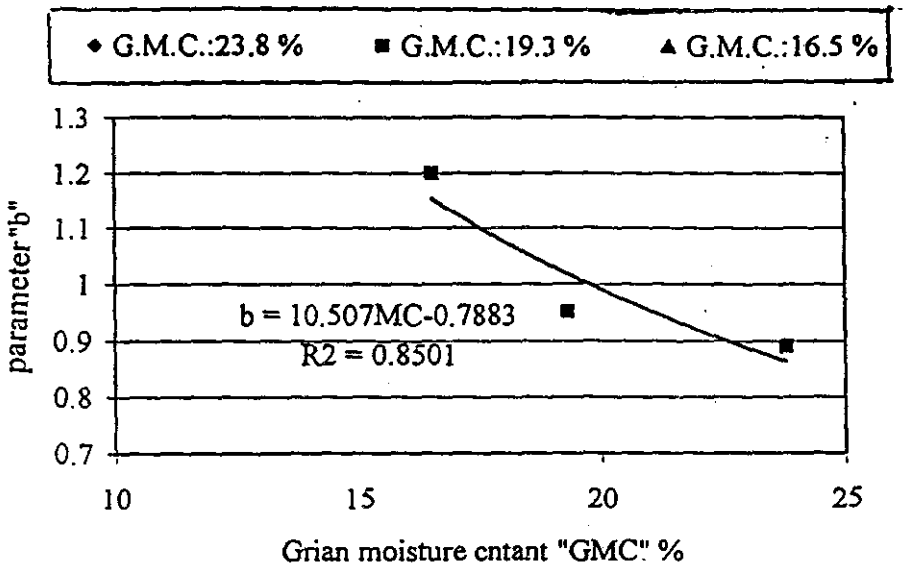

Fig. (4.8) : Relatino between parameter "b" and grain moisture content "G.M.C." total loss "T_L" in rice crop.

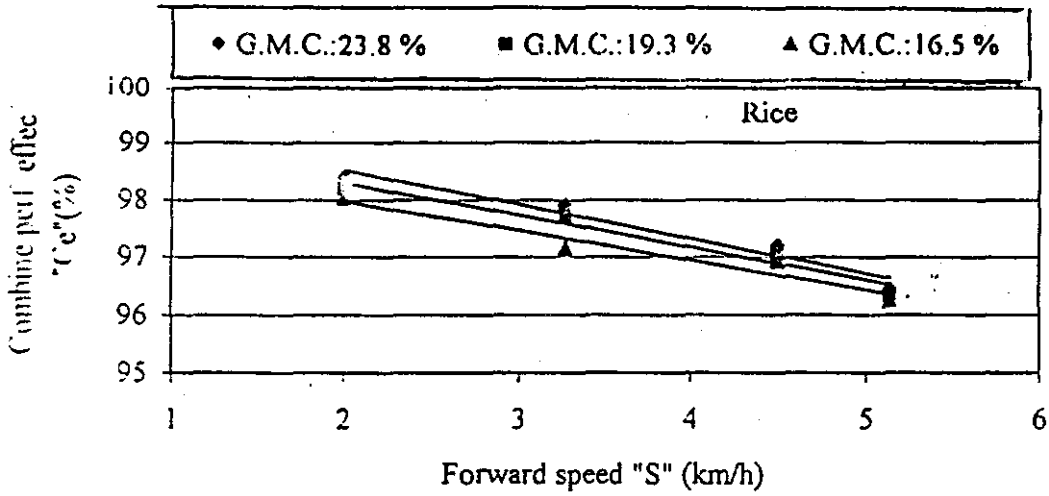

Fig. (4.9) : Relation between combine performance efficiency "Ce" and forward speed "S" at grain moisture content "G.M.C." and straw moisture content "S.M.C." in rice crop.

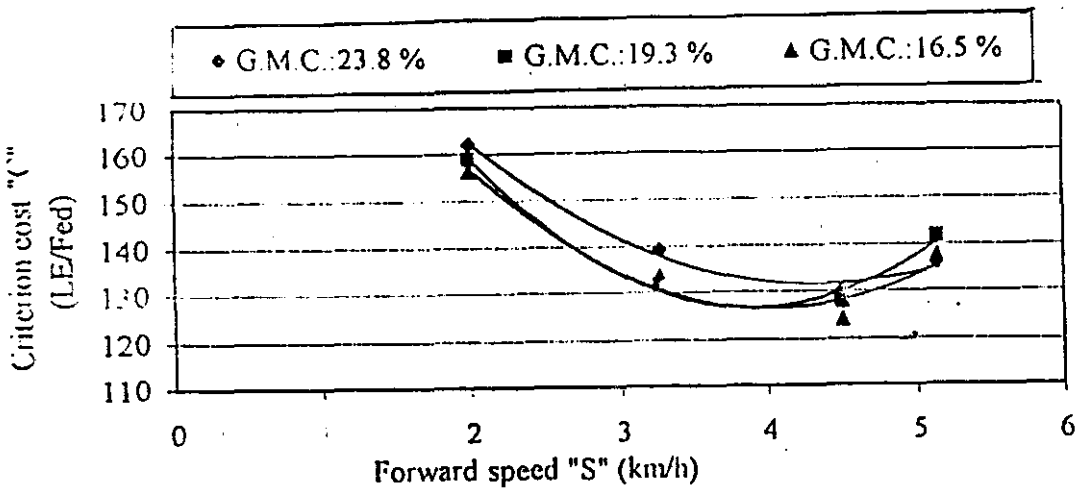

Fig. (4.10): Relation between criterion cost "C" and forward speed "S" at different grain moisture content "G.M.C.)" and straw moisture content "S.M.C."

4.3. Machine cost (L.E/fed):

The machine cost of rice harvesting by combine was considered through using the optimum conditions. The optimum forward speed was 4.5km/h, and the grain moisture content recommended at 16.5% which was the most suitable one. The equation used in calculation was (Awady, 1982) equation.

The results indicated that the machine cost for rice was about 58.96 L.E/fed.

4.4. Criterion cost "C" (L.E/fed):

The forward speed and grain moisture content had effect on comparative cost in harvesting process.

Fig (4.10) shows the criterion cost of harvesting rice. It shows that the criterion cost tends to decrease at increasing forward speed.

The criterion cost at forward speed 5.14 km/h increased from 136.13 to 137.63 L.E/fed at different grain moisture contents. This increase depends on increase of total losses cost at this speed and at different grain moisture contents.

5. SUMMARY AND CONCLUSION

The objectives of this study were to improve the harvesting process as: decreasing of harvesting losses, determination of forward speed suitable for combining, determination of air fan velocity for shoe (cleaning) and determination of the moisture content suitable for harvesting.

- Header losses:

The header loss "H_L", forward speed "S" and grain moisture content "GMC" has been involved into an equation as:

$$H_L = -0.119\ GMC + 0.053\ S^2 - 0.25\ S + 3.3$$

- Threshing losses "Th_L":

The threshing loss "Th_L", forward speed "S" and grain moisture content "GMC" are involved into the following equation.

$$Th_L = (0.014\ GMC - 0.072)\ S^{O}.57$$

- Separating losses "SP_L" :

The separating loss decreases with decreased grain moisture contents at all forward speeds from 2.0 to 5.14 km/h, with decrease

of grain moisture content from 23.8 to 16.5% .

- Shoe (cleaning) losses" Sh_L" :

The shoe loss increases with increasing of the forward speed from 2.0 to 5.14 km/h, increasing of air fan velocity from 6.17 to 7.67 m/s and decreasing of the grain moisture content from 23.8 to 16.5%.

-The total losses "T_L" :

The total loss increases at harvesting rice crop with increasing of the forward speed from 2.0 to 5.14 km/h and decreasing of the grain moisture content from 23.8 to 16.5%.

The total loss "TL", forward speed "s" and grain moisture content "GMC" has been involved into equation as :

$$T_L = (10.5\ GMC\text{-}O.79)\ S\hat{}O.76$$

- Criterion cost "C" :

The criterion cost for harvesting operation of rice crop decreases by the decreasing of the grain moisture content form 23.8 to 16.5% and increasing of the combine forward speed from 2.0 to 4.5 km/h. The criterion cost "C" decreased from 162.04 LE/fed at forward speed 2.00 km/h, and at grain moisture content 23.8% to 127.72 LE/fed. at forward speed 4.5 km/h and grain moisture content 16.5% for rice crop, but it increased at forward speed 5.14 km/h. to 133.68 LE/fed. This increasing may be due to increased total losses cost.

Recommendations:

From the previous results it can be recommended that:

1. The optimum operating harvesting rice crop was at combine forward speed 4.5 km/h, and grain moisture content of 16.5%.
2. The optimum air fan velocity during harvesting was 6.17 m/s, for rice.

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الملخص العربي

** **

دراسة فاقد الحصاد الآلي في محصول الأرز باستخدام جامعة الحبوب

أ.د / عبد القادر على النقيب[1] أ.د/ زكريا يونس عبد اللطيف[1]
د / علاء الدين على المسيري [1] م / عوض عبد الواحد [2]

أجريت هذه الدراسة على حصاد محصولي الأرز (سخا ١٠٢) بواسطة آلة الحصاد الجامعة Kupota PRO 481 اليابانية الصنع بمنطقة دمنهور، محافظة البحيرة خلال موسمي الحصاد (١٩٩٩م – ٢٠٠٠م) و (٢٠٠٠ – ٢٠٠١). واشتملت الدراسة على تأثير كلاً من العوامل الآتية على عملية الحصاد:

- السرعة الأمامية للآلة (S) وكانت (٣,٢٧,٢ و ٤,٥ و ٥,١٤ كم/ساعة) . المحتوى الرطوبي للمحصول (GMC) ، (٢٣,٨ و ١٩,٣ و ١٦,٥%) .
- سرعة هواء المروحة اللازمة للتذرية كانت (٦,١٧ و ٧,٠٣ و ٧,٦٧ م/ثانية)

وقد اتخذت المعايير الآتية للحكم على المتغيرات السابقة :

١- فواقد الآلة :- فاقد أمامي ، فاقد دراس ، فاقد فصل ، فاقد تنظيف ، كفاءة أداء الآلة ، التكاليف الكلية لعملية الحصاد .

وكانت النتائج كالآتي :

١- الفاقد الأمامي: "H_L" Header Loss زيادة السرعة الأمامية من ٢ إلى ٥,١٤ كم / س أثناء الحصاد أدت إلى زيادة الفاقد الأمامي من ٠,٢٦ إلى ١,٥ % عند تناقص المحتوى الرطوبي من ٢٣,٨ إلى ١٦,٥% .

أمكن ربط الفاقد الأمامي "H_L" بالسرعة الأمامية "S" والمحتوى الرطوبي "GMC" بعلاقة رياضية من خلال المنحنيات وكانت كالآتى :

$$H_L = 0.119\ GMC + 0.053\ S^2 - 0.25\ S + 3.3$$

٢- فاقد الدراس Threshing loss "Th_L"

أمكن ربط فاقد الدراس "Th_L" بالسرعة الأمامية "S" والمحتوى الرطوبي "GMC" بعلاقة رياضية كالآتي :

$$Th_L = (0.015\ GMC - 0.072)\ S^{0.57}$$

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(١) أستاذ ومدرس على الترتيب بقسم الهندسة الزراعية بزراعة الأزهر .

(٢) باحث مساعد بوزارة الزراعة .

٣- فاقد الفصـــل Separating loss "SP_L"

قـــل فاقـــد الفصل بانخفاض المحتوى الرطوبي من ٢٣,٨ إلى ١٦,٥% أثناء حصاد الأرز عند السرعات من ٢ إلى ٥,١٤ كم/ساعة .

٤- فاقد التنظيف Shoe loss "Sh_L"

زاد فاقد التنظيف بزيادة السرعة الأمامية للآلة من ٢ إلى ٥,١٤ كم / ساعة وزيادة سرعة هواء المـــروحة مـــن ٦,١٧ إلى ٧,٦٧ متر/ثانية وانخفاض المحتوى الرطوبي ، وقد نلاحظ انخفاض كمية الفاقد بانخفاض سرعة هواء المروحة من ٧,٦٧ متر/ثانية إلى ٦,١٧ متر /ثانية أثناء عمليات الحصاد.

٥- الفواقد الكلية Total loss "T_L"

وقد لوحظ زيادة الفاقد الكلي بزيادة السرعة الأمامية من ٢ إلى ٥,١٤ كم/ساعة ، وانخفاض المحتوى الرطوبي في محصول الأرز من ٣٢,٨ إلى ١٦,٥% ، "T_L" مع السرعة "S" والمحتوى الرطوبي "GMC" كالآتي:

$$"T_L" = 10.5\ GMC^{-0.79}\ S^{0.76}$$

٦- التكاليف

تقـــل التكالـــيف الكلية أثناء عملية الحصاد لمحصول الأرز بزيادة السرعة الأمامية من ٢ إلى ٤,٥ كـــم/ســـاعة وانفخاض المحتوى الرطوبي للأرز، ولكن تزادا قيمة التكاليف عند السرعة ٥,١٤ كم/ساعة وربما ترجع هذه الزيادة في التكاليف بزيادة قيمة تكاليف الفاقد الكلي في الأرز، عند حصاد الأرز كانت التكالـــيف من ١٦٢,٤ إلى ١٥٦,١١ جنيه/ف ، ١٣٩,١٧ إلى ١٣٣,٤٩ جنيه /ف ، ١١٢٩,٨٣ إلى ١٢٣,٩٢ جنيه/ف عند زيادة السرعات من ٢ إلى ٤,٥ كم/ س وانخفاض المحتوى الرطوبي من ٢٣,٨ إلى ١٦,٥ لمحصـــول الأرز ، ولكـــن زادت التكاليف عند سرعة ٥,١٤ كم/ س من ١٣٦,١٣ ، ١٣٧,٦٣ جنيه/ف وذلك لزيادة قيمة الفاقد الكلي عند هذه السرعة.

التوصيـــــــات :

من خلال النتائج السابقة يمكن التوصل إلى التوصيات الآتية :

١- أنـــسب تشغيل اقتصادي لحصاد محصول الأرز كان عند سرعة أمامية للآلة ٤,٥ كم/ساعة .

٢- أنـــسب محتوى رطوبي للحبوب ١٦,٥% للأرز.

٣- أنـــسب سرعة هواء للمروحة اللازمة لعملية التذرية هي ١٦,١٧ متر/ثانية .