**RUFORUM Working Document Series (ISSN 1607-9345) No. 14 (2): 1085 - 1094.
Available from *http://repository.ruforum.org***

Research Application Summary

Performance evaluation of self-propelled sesame harvesting cutter binder under Gedarif farming conditions, Gedarif State, Sudan

Elebaid, J. I., Abdalla, S. A. & Osama, A. M.
Department of Agricultural Engineering, Faculty of Agricultural Sciences, University of Gezira, Wad madani, Sudan
Corresponding Author: osamaabbas11@yahoo.com

Abstract

Sesame *(Sesamum indicum* L.) is one of the important oil crops in the rainfed sector of the Sudan. The crop ranks third in cultivated area after sorghum and millet. It draws its importance from its use as a food crop, a raw material for industry, feed for livestock and as a leading export crop. Mechanical harvesting of sesame is becoming extremely important in the Sudan since the hand harvest becomes more difficult to use due to the rapid expansion in areas under production and the scarcity and high cost of labour coupled with the timely operation needed at harvest. Partial to complete mechanization of sesame harvest has been tried using a variety of machines with different levels of success. The main objective of this study was to assess and evaluate an Italian cutter binder and to compare its performance with the conventional sesame manual harvesting methods. The cutter binder measured parameters were speed, field capacity, field efficiency, fuel consumption, twine consumption, bundle size, bundle drying and plant losses. Crop measurements parameters included; plant height, first capsules height from ground, cutting height and plant population. Results showed that the binder was superior to the traditional harvesting method with respect to the speed (7.8 km/hr), field capacity (5.1 fed/hr) and field efficiency (77.3). The cutter binder resulted in 0.85 L/fed fuel consumption, 223 m/fed twine consumption, 22 cm in diameter bundle size, completely dried bundle and no plant cutting losses. The binder produced very good tied bundles with the least total plant height of 70 cm from ground level, while there was no problem with plants taller than this height. This research has shown that the cutter binder was a good alternative to sesame manual harvesting methods.

Key words: Cutter binder, performance, self-propelled, sesame harvesting

Résumé

Le sésame (*Sesamum indicum* L.) est l'une des importantes cultures oléagineuses dans le sec-teur de l'agriculture pluviale du Soudan. La culture occupe le troisième rang en superficie cul-tivée après le sorgho et le millet. Elle attire son importance de son utilisation comme une cul-ture vivrière, une matière première pour l'industrie, l'alimentation du bétail et en tant que cul-ture d'exportation de premier plan. La récolte mécanique de sésame devient extrêmement im-portante au Soudan depuis que la récolte à la main devient de plus en plus difficile en raison de l'expansion rapide dans les zones sous la production et de la rareté et le coût élevé de la main-d'œuvre couplés avec le fonctionnement en temps opportun nécessaire à la récolte. Un effort partiel de la mécanisation de la récolte de sésame a été essayé en utilisant une variété de machines avec différents niveaux de succès. L'objectif principal de cette étude était d'évaluer une machine italienne ''Cutter binder'' et de comparer ses performances à la méthode conven-tionnelle de sésame à la main. Les paramètres mesurés de cette machine étaient la vitesse, la capacité au champ, l'efficacité au champ, la consommation de carburant, la consommation de la ficelle, la taille des rouleaux, le séchage des rouleaux et les pertes en plante. Paramètres de mesures de récolte inclus; hauteur de la plante, hauteur du sol à la première capsule, la hauteur et la population de la coupe de végétaux. Les résultats ont montré que la méthode de récolte utilisant la machine '' Cutter Binder'' était supérieure à la méthode classique de récolte par rapport à la vitesse (7,8 km / h), la capacité de champ (5.1 prélèvement/ h) et de l'efficacité sur le terrain (77,3). La machine conduit à une consommation de 0,85 L de carburant par prélè-vement, 223 m de consommation en ficelle, 22 cm de diamètre de la taille des rouleaux, des rouleaux complètement séchés et aucune perte en plante. Le ''Cutter Blinder'' a produit de très bons rouleaux avec une hauteur totale moyenne de plante de 70 cm du niveau du sol, et il n'y avait pas de problème avec des plantes plus hautes que cette hauteur. Ces recherches ont montré que le ''cutter binder'' était une bonne alternative à la méthode manuelle de récolte du sésame.

Mots clés : Cutter Binder, performance, Auto-poussé, récolte du sésame

---

Background

Sesame (*Sesamum indicum)* is one of the most important oilseed crops in the world. It is well suited to different crop rotations and is mostly grown under moisture stress with low management inputs by small holders (Ashri and van Zanten, 1994). Having an annual or perennial bush forms, sesame is an important commercial crop adapted to tropical and subtropical areas. Globally, drought stress is one of the most important environmental factors limiting sesame production (Betram *et al.,* 2003). The other challenge relates to diffiulty in harvesting the crop. It is produced under rainfed system in the Sudan and it ranks third in cultivated area after sorghum and millet. Sesame draws its importance from its use as a food crop, a raw material for industry, feed for livestock and as a leading export crop. Sudan ranks second in sesame exports and accounts for 80% and 40% of all cultivated sesame area in the Arab world and African continent, respectively (Abdalla and Abdel Nour, 2001).

Several harvest methodologies for sesame exist throughout the world (Weiss, 1971). The mature plants are cut, bundled, and stocked to dry. In some areas the stocks are left in the field. In other areas the bundles are moved to a stocking fence as is the practice in parts of Africa or to a threshing floor as practiced in parts of India. As the plants dry, the capsules open and some seeds can fall out. On the threshing floor, the stocks can be moved every few days as the seed is collected but if drying is in the field, the fallen seeds are lost. Mechanical harvesting of sesame is becoming increaingly important in the Sudan since hand harvest becomes more difficult due to the rapid expansion in areas under production and the scarcity and high cost of labour coupled with the timely operation of harvest. Partial to complete mechanization of sesame harvest has been tried using a variety of machines with different levels of success. The objectives of this study was to evaluate the performance of the self-propeller binder for sesame harvesting and to compare it with manual harvesting under two methods of sowing, row and broadcasting.

Literature summary

Sesame harvesting should essentially start when the seeds in the lower pods have ripened. At this stage the capsules are still greenish in color, with a high moisture content, most of the leaves turn yellow and shed. The stems may be cut near ground level and then bound and stoked in the field to ripen the seed. With dehiscent types or when harvesting is delayed, it is usually better to cut the heads and dry them in bundles hanging downwards on racks for 1-2 weeks. As they ripen, the seeds fall on mats placed below the racks. The heads may also be shaken to dislodge the seeds or threshing is done by beating with a stick. The indehiscent cultivars may also be harvested mechanically. (Onwueme and Sinha, 1991).

There is a limited level of sesame mechanization in many countries. In Venezuela, the plants are cut with a binder, manually stocked, and then combined mechanically. Some farmers manually pitch the stocks into the combine while others use an ingenious device to slam the stock into an auger that feeds it into the combine (Langham *et al.,* 2006). Harvesting is the most difficult and time consuming of the operations of sesame production and is estimated to constitute 60% to 70% of the total cost of production in the Sudan (Osman, 1966). In addition, harvesting has to be carried out within a short time, about two weeks after physiological maturity. This is necessitated by the indeterminate growth habit of the plant, the lack of uniformity in reaching maturity and especially the dehiscence of the pods upon drying. Early harvesting results in reduction in yield while delayed harvesting, until the top capsules are ripe, leads to splitting of the lower pods and shedding of most of their seeds.

Kaushal *et al.* (1969) found that harvesting sesame plants when the capsules had turned yellow gave the highest (53.4%) seed oil content; further delay in harvesting resulted in seed shattering without increase in oil content while harvesting at early stages reduced oil content. Mechanical harvesting of sesame is becoming a necessity in the Sudan since hand harvesting is a difficult operation with the expansion of areas under the crop and the scarcity of labor and drinking water in the production areas. Growing sesame is a risky enterprise. The farmer may be in a state of panic at the time of harvest due to labor shortage and due to the fact that the time is very short between physiological maturity and loss of seed by shattering. This leads to ever-increasing costs of cutting, stacking and threshing (Osman, 1966).

There is a large variation in sesame production areas in Sudan from a year to another particularly in modern sector (mechanized sector). This variation refers mainly to variation in rainfall amounts and distribution and the fluctuation in prices for the commodity. The area of sesame under Gedaref area (mechanized sector) is varied from year to year due to the same reasons mentioned. Mechanical or semi- mechanical harvest became necessary because of the importance of the horizontal expansion of the crop. In addition to continuous lack of man- power and lack of drinking water at the time of harvest in the areas of production.

Study description

The experiment was carried out during seasons 2008/2009 and 2009/2010 in Elgedaref State, Sudan. The soil was heavy cracking clay, characterized by low water holding capacity and poor internal drainage. In manual sesame harvesting, plants were cut by hands bellow the lower capsules by using sickles or knives to make bundles. Each four bundles were put together upwards in a pyramidal shape to make tokol (tokol is four bundles of sesame plants put together in pyramid shape). Each hundred (tokol) made Hilla (Hilla is about hundred tokol or 400 bundles). The bundles in Hilla were located into two rows each opposite to the other under sunlight to dry. In mechanical harvesting, the binder was adjusted to cut and bind sesame plants. The cutting level was under the lower capsules and bundles were collected manually and each four bundles put together for drying.

For estimating the plant population, a square meter was used randomly for each treatment. Twenty replications were taken at random and the mean count for the replications obtained. These measurements were carried out after plants were cut by using the binder. For measuring plant height and first capsules height from ground, a metal meter was used. Twenty replications were taken randomly and the mean count obtained.

Research application

Plant parameters

The results show that plant height ranged from 85 to 180 cm as minimum and maximum, respectively, with 116 cm as average(Table 1). These differences in plant height could be attributed to the weed competition, water logging for low spots and water stress for high spots. The plants heights enabled the binder to operate efficiently and produced very good bundles. A suitable tied bundle depend mainly on plant height and cutting height. In order to produce a very good tied bundle, the part of the plant over tying position should be at least equal to the clearance between cutting level and tying (knotting) level (approximately 30 cm). Accordingly, the cutting height of 25 cm and the total plant height of 85cm obtained a good bundle.

The cutting height of the binder is continuously changed during operation according to the unleveled soil surface and operator's judgment. Therefore, cutting level was adjusted to a variable level bellow bottom capsules height from ground surface. Lowering of the cutter bar to a low level in soils containing an obstacle (such as gravel) may cause cutter bar damage. The cutting height ranging from 19 to 31cm as minimum and maximum, respectively, while 25cm was the average (Table 1). These differences in cutting height as stated before relate mainly to unleveled ground surface and machine bumping and vibration.

Bottom capsules height ranged from 28 cm as minimum and 60 cm as maximum, with 40 cm as an average (Table 1). This variation in bottom capsules from ground might be attributed to the variation in plant height and weed infestation. As indicated earlier, the average cutting height was 25 cm, while the average bottom capsules from ground was 40 cm, which provide good opportunity for capsules of individual plants to be contained in the bundle. Also, the adjustment of cutting level to a clearance of 25 cm prevents machine cutter bar from damage.

Table 1. Plant parameters during first season from different locations of Gedarif State

Item	Maximum	Minimum	Average
Plant population	241200	77280	161724
Plant height (cm)	180	85	116
First capsule height (cm)	60	28	40
Cutting height (cm)	31	19	25
Number of branches	12	2	5
Number of bundles/fed	285	240	261

Binder performance

The theoretical field capacity (fed/hr) and effective field capacity were calculated for the binder. The results shows that 5.4 and 7.8 fed/hr was the minimum and maximum theoretical field capacity measured, respectively, with a 6.6 fed/hr average (Table 2). Also, the results indicates that 4.3 and 6 fed/hr was the minimum and maximum of effective field capacity measured, respectively, while 5.1 fed/hr was the average. These results show the superiority of this binder to the modified binder with a bundle carrier that was reported by Elghali *et al.* (1992), which had field capacity of 2.5 fed/hr. Comparing the binder field capacity to hand working, the binder is better than manual labour. A good prepared and established sesame crop usually requires about 4-5 workers for cutting one feddan a day. In this study, the binder performed in one shift the equivalent of 200-250 workers perform per day.

Table 2. Avearge binder performance from different locations of Gedarif State.

Variable	Minimum	Maximum	Average
Theoretical field capacity (fed/hr)	5.4	7.8	6.6
Effective field capacity (fed/hr)	4.3	6	5.1
Efficiency (%)	51.5	90.9	77.27
Fuel consumption (L/fed)	0.57	1.2	0.85
Number of bundles/fed	240	285	261
Twine consumption (m/fed)	167	351	223
Bundle collection workers (worker/day)	7	30	14

The minimum and maximum binder field efficiency was 65 and 90.9%, respectively Table 2, while average field efficiency obtained was 77.27%. This percentage indicated that the binder worked efficiently through the whole area except in very bad soil surfaces. The binder consumed fuel on average about 0.57 and 1.2 liters/fed as minimum and maximum, respectively, with 0.85 liters as average (Table 2). With a binder equipped with a medium fuel tank (10 gallon capacity), this would enable the binder to accomplish about 47 fed/tank if the binder operated with the same average fuel consumption rate (0.85liter/fed).

The number of bundles per feddan ranged from 240-285 bundles with an average of 261 bundles (Table 2). These variations in the number of bundles per feddan arises from the variation in plant population and plant branching. It was noticed that the bundles were completely dried up when mature plants that were cut with less or without leaves. The bundles made by the binder, and even those included weeds were completely dried up at the same time given for the manual bundles (two weeks). Bundle size ranged from 20 to 25 cm in diameter depending on spring setting in one of seats 2, 3 or 4 respectively. Machine-made bundles were larger in size compared to the hand-made bundles (plate 1).

Plate 1: Machine bundles

The twine used for one feddan is estimated by the number of bundles and twine used for one bundle. The twine length differed from feddan to feddan depending on the plant population. The twine length used for one feddan ranged from 167 to 351 meter/fed with 223 meters average. There were no loss of plants (uncut plants, cut and untied plants and inverted plants) during operation except those shorter than the knotting level. These results are in agreement with those of Ahmed (1983) and Sumsum (1998) who recorded 8 % and 9 % losses for modified binder, respectively. The binder cuts and binds all plants without losses when binding device operate efficiently. But when there is loosening in the binding twine there will be no binding for bundles and then the plants scatter.

The common problems affecting the knotting device were the twine type, sesame plant height, and loosening of the knife in addition to timing gears failure caused by loosening of the belt. Short sesame plants were usually tied at the top producing a pyramidal shape bundle which oftenly scattered. The largeness and variation in bundle size was still larger than the farmers preferred.

The binder was not provided with a device for absorbing shocks since the machine was designed in a rigid frame. Therefore, the machine was severely affected by vibration and bumping when operated through uneven soil surface. In addition to that, the area of the experiment was prepared by using a wide level disk which resulted in furrows and depressions. The binder was provided with narrow wheels and the width section of the tire was not enough to absorb machine bumping during operation, particularly through uneven soil surface. Further, the binder was not equipped with closed cabin to protect the operator. Therefore, most of the binders in many sites were operated for one shift a day because there was a large number of insects at night. These insects were attracted by machine light.

Cost of sesame harvesting

The cost of manual harvesting of sesame depends mainly on the number of Hilla´s/feddan and price of Hilla (hilla is four hundred bundles of sesame plant put together after cutting under sun light to dry). Both number of Hilla's and price fluctuate from one year to another. Variation in the number of Hilla´s/feddan refers to the plant population, weeds infestation and sesame branching. In manual cutting, number of Hilla's/feddan is not fixed due to the bundle size which differ from one worker to another (plate 2). In manual harvest workers are paid per number of Hilla's and not per area. The number of Hilla´s and price obtained from studied area was 4 Hilla/fed and 8 (SDG)/Hilla, respectively.

Plate 2: Manual bundles.

The bundle size made by the binder ranged from 20 to 25cm in diameter. The number of bundles per feddan refers to the density and branching of the crop. The number of bundles obtained in experimental area was 125 bundles/fed. The average length of twine used for tying one bundle was 80 cm. The length of twine used for one feddan depends on the bundle size and number of bundles/feddan. The total length of twine used for one feddan was 100 m (0.80 m/one bundle x 125 bundle/feddan).

In manual harvesting, sesame growers need to bring a large number of workers to cut the crop, particularly, in large fields. Farmers usually meet the additional costs for workers transport, food, water and accommodation as well as health care. The price of manual cutting of sesame fluctuates continuously during the period of harvesting especially when the crop is fully matured. From the comparison of both harvesting methods it was found that the mechanical harvesting cost was lesser than manual harvesting. The operation cost of manual harvest (Table 3) was estimated only for one worker/day. However, well established crop usually requires 4-5 workers for cutting one feddan/day. This translates to about 50 SDG/fed as compared to mechanical harvest cost (45.6 SDG/fed).

Table 3: Operation cost of the two harvesting methods per feddan (SDG).

Operation cost	Manual	Mechanical
Cutting cost	32	40
Bundles collection	-	3 (under bargaining)
Tools for cutting	1	-
Cost of sacks	equal	equal
Labor transport (one worker/day)	1	-
Livelihood (food) /one worker a day	3	-
Drinking water/day	1	-
Threshing	equal	Equal
Cost of twine	-	2.6
Total cost	38	45.6

Acknowledgement

University of Gezira and the Agricultural Research Corporation of Sudan for supporting this research. This paper is a contribution to the 2016 Fifth African Higher Education Week and RUFORUM Biennial Conference.

References

Abdalla, A.A. and Abdel Nour, H.O. 2001. The agricultural potential for Sudan. Executive Intelligence Review. 37-45 pp.

Ahmed, E.E 1983. Mechanization of Sesame Harvesting. M.Sc. thesis, Faculty of Agriculture, University of Khartoum, Shambat, Sudan

Ashri, A., and van Zanten, L. 1994. Introduction. pp. 21–23. In: Report of the 1st FAO/IAEA Research Co-ordination Meeting on Induced Mutations for Sesame Improvement, 21–25 March 1994, Vienna, Austria. IAEA.

Betram, K., Janssens, M.J.J. and Abdalwahab, A. 2003. Breeding for drought tolerance in sesame (*Sesamum indicum*). pp 135. In: Conference on Technological and Institutional Innovations for Sustainable Rural Development, 8–10 October, 2003, Deutscher Tropentag, Gottingen.

Elghali, A.G., Eltayib, S.M., Elfaki, M., Gido, Y.I. and Bakheet, M.A. 1992. SIM Mechanized Dry land Farming Project. 1992. Annual Report. Sim Sim Applied Research Narrative. Volume II.

Kaushal, P.K., Sawant, A.R. and Dhagat, N.K. 1969. Oil content in Sesamum at various stages of maturity. *JNKVV Research Journal* 3: 53 - 54 (cited after Field Crop Abstract 24: 333, 1971).

Langham, D.R. 2007. Phenology of sesame. In: Janick, J. and Whipkey, A. (Eds.), Issues in New Crops and New Uses. ASHS Press, Alexandria, VA, 144–182 pp.

Langham, D. R., Smith, G., Wiemers, T. and Riney, J. 2006. Sesame Growers Pamphlet.

Sesaco Corporation. Lubbck, San Antanio. Texas.

Onwueme, I.C. and Sinha. T.D. 1991. Field crop production in tropical Africa. 2nd Edition. Technical Center for Agricultural and Rural Co-operation, CTA, Ede, Netherlands. 480 pp.

Osman, M.S. 1966. The possibilities of mechanization of agricultural production in the Sudan. In: Agricultural Development in the Sudan. Proceedings of the 13th Annual Conference, Philosophical Society of the Sudan.

Weiss, E.A. 1971. Castor, sesame, and safflower. Leonard Hill Books, London. pp.311–525.