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REQUIRMETS OF THE MECHANICAL KARKADI (*Hibiscus Sabdariffa* L.) FLOWERS HARVESTING.

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ABSTRACT

Karkadi (Hibiscus sabdariffa L.) plant is one of the oldest plant famous in Egypt. Its sepal is the economic benefit to edible, industrial and medical. While, its seed is very important yield also. It content about 20 % edible oil (Komarov, 1968). The Karkadi sepals separating is still done by hand in the many countries. This method cause high losses and polluting the sepals yield. The aim of this research to investigate a simple manual equipment to harvest Karkadi flowers and to separate the sepals - fruit in the field. Three parameters were selected to test the manual equipment: knives angles (30, 60 and 90°), Karkadi species (light red-I, dark red and light red-II) of variety Sabahia 17 and harvesting period at the same season to allow the flower ripe (started from 20 days after flowering) (15th Nov., 30th Nov. and 15th Dec.) by equipment and 30th Nov. by handing. The measurements to determine the specification of Karkadi flower the sepals length, fruit length and diameter, flower nick tensile forces and sepal shear force were measured. Therefore, to evaluate the harvesting methods fruit quality, mass of Karkadi (flower, fruit and sepals), number of flowers/plant and yield of fresh sepals Karkadi compared with the traditional harvesting system were estimated.

The results cleared that the highest sepals length was 73.4 mm, highest fruit length of 41.09 mm, highest fruit diameter of 19.39 mm, for light red-II. Then the flower nick tensile force of 101.3 N at knives angle of 90° and sepal shear force of 5.87 N at dark red species. Therefore, the fruit quality (undamaged) 98 % for light red-II, heaviest mass of Karkadi (flower, fruit and sepals) were 12.96, 5.36 and 7.60 g respectively for the previous species. The light red-I species gave the highest number of flowers/plant of 221.6 and yield of fresh sepals Karkadi was 5340.56 kg/fed. It increased about 22.32 % compared with the traditional harvesting system. The research concluded that the suitable use of the investigated manual equipment to harvest the Karkadi flowers at the knives angle of 60°. But the harvest done periodically to allow the time for the all flowers ripe, that increased the yield income per area.

Keywords: Karkadi, Hibiscus Sabdariffa L., Sepals, Fruit, Flower, Knives, Angle, Tensile force, Shear force, harvest, equipment.

INTRODUCTION

Hibiscus sabdariffa L. (Family Malvaceae) is an annual shrub, widely grown in Central and West Africa. More than 300 species of hibiscus are distributed in tropical and subtropical regions with a good rainfall distribution (Duke, 1978). Naturland and Kleinhademer (2000) informed that the main producers of hibiscus blossoms are Egypt, Sudan, Mexico, Thailand and China. Annual cycle shrub, it reaches up to 1.80 m high, little branched stem, cup-shaped, glabrous and red tonality (McCaleb, 1998). The flower of hibiscus is a single, sessile and axillar possesses its corolla made up of five petals with an average 5–10 cm diameter when opened. Five sepals of intense and white to pale yellow with a dark red spot at the base of each petal, and have a stout fleshy calyx at the base, 1.5–2.0 cm wide, enlarging to 3.0–3.5 cm, fleshy and bright red as the fruit matures. The fruit is an oval dehiscent capsule, 2.0 cm long, where are inserted seeds and stays involved by the calyx developing after

fecundation (Duke, 1978). Hassan (2007) found that the plant height, number of fruits/plant and mass of fresh sepals/plant average were 1.77 m, 151 and 604 g respectively. The yield of dry sepals of 30-450 kg/fed., fiber of 500-700 g/fed. And the oil of Karkai was 400-500 kg/fed. Kotb (1997).

It is an annual plant, and takes about six months to mature. The red calyces of the plant are increasingly exported to America and Europe (François et al. (ipho@fao.org)). The production of hibiscus calyces in developing countries becomes important for income generation activities for the benefit of rural communities (Diatta and James, 2007). Egypt is the oldest country use the Karkadi (Hibiscus Sabdariffa L.) dried calyxes as tea. It main palnted in the upper Egypt. The dry sepals production are 4871 ton from 8664 feddans at 2005 season (Ministry of agricultural, 2007). Most hibiscus species are used as ornamental plants, but many are used to produce a tea from dried sepals. This tea is called "drink of the Pharaohs". Hibiscus is also used in the food and pharmaceuticals industry (Bulatov and Haddad, 2002). Hibiscus sepals contents of anthocyanin, protein, organic acids, phenol carbonic acids, vitamin C, anthocyanins and polysaccharides found. Sepals of hibiscus flowers are used to make a floral fruit tea or mixed with other herbal teas. Yadong et al. (2005). Flordejamaica @ yahoo.com (2006) reported that the fresh calyx (the outer whorl of the flower) is eaten raw in salads, is cooked and used as a flavoring in cakes and is also used in making soups, sauces, pickles, puddings etc [Komarov (1968), Hill (1952), Facciola (1990), Duke (1983)]. The calyx is rich in citric acid and pectin and so is useful for making jams, jellies etc. [Chopra et al. (1986), Duke (1983)]. It is also used to add a red color and to flavor to herb teas [Bown (1995), Duke (1983)], and can be roasted and used as a coffee substitute. A refreshing and very popular beverage can be made by boiling the calyx, sweetening it with sugar and adding ginger. Seed - roasted and ground into a powder then used in oily soups and sauces [Kunkel (1984), Facciola (1990)]. The roasted seeds have been used as a coffee substitute that is said to have aphrodisiac properties [Duke (1983)]. The seed yields 20% oil. This is probably edible (Ken Fern Notes)). The hibiscus have diuretic effects, to help lower fevers and is antiscorbutic [Komarov (1968), Bown (1995)]. The fruits are antiscorbutic. The flowers contain gossypetin, anthocyanin, and the glycoside hibiscus. These may have diuretic and choleretic effects, decreasing the viscosity of the blood, reducing blood pressure and stimulating intestinal peristalsis [Duke (1983) and Chopra et al. (1986)]. The leaves and flowers are used internally as a tonic tea for digestive and kidney functions [Komarov (1968), Bown (1995)]. The ripe calyces are diuretic and antiscorbutic. The succulent calyx, boiled in water, is used as a drink in the treatment of bilious attacks. The seeds are diuretic, laxative and tonic. They used in the treatment of debility. It is used as a folk remedy in the treatment of abscesses, bilious conditions, cancer, cough, debility, dyspepsia, dysuria, fever, hangover, heart ailments, hypertension, neurosis, scurvy, and strangely [Duke (1983)].

François et al. (ipho@fao.org) cleared that the harvest is timed according to the ripeness of the seed. The fleshy calyces are harvested after the flower has dropped but before the seedpod has dried and opened. The more time the capsule remains on the plant after the seeds begin to ripen. Special care must be taken during harvesting operation to avoid contamination by extraneous material.

At no time should the calyx come in contact with the ground or other dirt surfaces. Clean bags or containers should be used to transport from the field to the drying location. Different harvesting methods are in use today. In Mexico the entire plant is cut down and taken to a nearby location to be stripped of the calyces. In China only ripe calyces are harvested with clippers leaving the stalks and immature calyces to ripen in the field. The field is harvested approximately every ten days until the end of the growing season. The calyx is separated from the seedpod by hand, or by pushing a sharp edged metal tool through the fleshy tissue of the calyx separating it from the seedpod.

Kotb (1997) developed and tested the three equipments to separate the sepals from the Karkadi flowers after harvesting. He found that the force required to sepals separation falling the experimental conditions into consideration, the separation force was estimated with 90 N. He also added that, the suitable orifice diameter range between 24 to 26 mm, which give high separation percent and low separation strength capacity. The equipment productivity 9.25 kg sepals per hours.

From above focus on Karkadi plants specification in order to obtain the optimum-harvesting equipment indicated that, until now there is no appropriate equipments realizing the harvesting requirements. Therefore, the aim of this paper is to demonstrate that, in case of a harvesting the flowers (sepals and fruits), physical and characteristics of three Karkadi species, and to investigate a manual equipment to separate the sepals and the fruit in the field.

Theoretical investigation

A mathematical analysis was developed to provide a complete understanding, which describe the press operation on the base part of the sepal by the four fingers (Fig 1). Then the sepal separate according to the following analysis. Referring to Fig.1 the analysis of forces acting on the sepal is:

$$\frac{m}{4} g \sin\alpha - N + \frac{t}{4}\sin\alpha = 0 \quad (1)$$

$$\mu N + \frac{m}{4} g \cos\alpha + \frac{t}{4}\sin\alpha = 0 \quad (2)$$

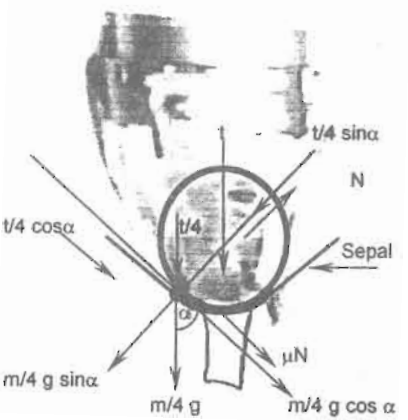


Fig. 1: The momentum position of separating sepals.

From Eq. (1)

Then;
$$N = \frac{m}{4} g \sin\alpha + \frac{t}{4} \sin\alpha \quad (3)$$

Substituting "N" values from Eq. (3) to Eq. (2), we found that:

$$\mu \frac{m}{4} g \sin\alpha + \mu \frac{t}{4} \sin\alpha + \frac{m}{4} g \cos\alpha + \frac{t}{4} \sin\alpha = 0$$

Where:

m: The mass of Karkadi flower, g.
α: Inclination angle of finger, degree
N: Reaction force acting of the sepals, N.
μ: Coefficient of friction between the sepal of Karkadi and the finger,
g: Gravitational acceleration, m/s^2
t : The press force, N
a: Sepal acceleration on the inclination of contact the sepal with finger surface, m/s^2

By substituting the Newton equation of the sepal motion at one finger then,

$$F = m\ a$$

$$\mu \frac{m}{4} g \sin\alpha + \mu \frac{t}{4} (\sin\alpha + \cos\alpha) + \frac{m}{4} \cos\alpha = F_1$$

$$\frac{m}{4} g(\mu \sin\alpha + \cos\alpha) + \frac{t}{4} (\mu \sin\alpha + \cos\alpha) = F_1$$

For the four knives then; $\therefore F_{total} = mg(\mu \sin\alpha + \cos\alpha) + t(\mu \sin\alpha + \cos\alpha)$

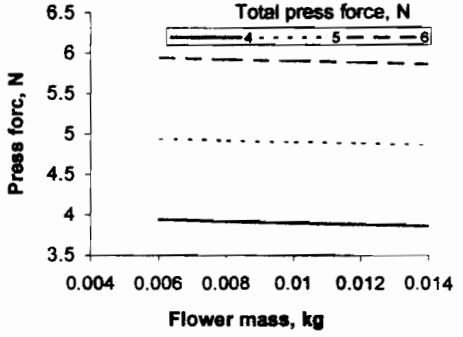


Fig. 2: The relationship between Karkadi flower mass and press force.

Fig. (2) clear the relationship between Karkadi flower mass and press force to separate sepal at different press forces. The figure illustrate that the press force slightly decreasing by increase the flower mass at different total force. Then the press force increase from 3.86 N to 5.86 N by increase the total press force from 4 to 6 N at the same flower mass.

MATERIALS AND METHODS

The experimental was conducted at El-Gemiza and El-Kasassen Research Sations during 2006-2007 seasons.

1- The manual equipment

A simple maual equipment made in Mansoura University work shop. It consists of three parts (Fig. 3). The first; is the cylindrical tube. It made of steel sheet of 2 mm thickness, 50 mm diameter and 146 mm length. Its used as a passing Karkadi fruit to cotton basket. The fruit basket supported on the tube side.

The second part; connected with the lower end of the tube. It consists of four fingers each one made from iron sheet of 1 mm thickness, 80 mm long and 16 mm width. The sharp knive was supported on the inside surface of fingers and at the level of 10 mm up to the lower fingers surface.

The third part; is an arm. It supported in the fingurs frame and the lower part of the arm shaped as a half circle (50 mm diameter) to connect the sepals basket.

2-The Karkadi plant characteristics

Three species of Karkadi (Hibiscus sabdariffa L.) Sabahia 17 variety was planted in El-Gemiza and El-Kasassen Research Sations. Table (1) shows some Karkadi species characteristics and Fig. (4) shows its flower dimensions. Karkadi flower is begin harvest at half of November (15th Nov.) after 15 to 20 days fruiting. The lower flowers are the first ripe then in the direction of the upper gradually.

3- The traditional harvesting method

The sepals are harvested after the flower has dropped but before the seedpod has dried and opened at 30th November. In Egypt, the plant is cut down and taken to a nearby location to be stripped of the sepals by hand.

The studied parameters are three Karkadi species (light red-I, dark red, and light red-II) its varying in flower shape and size, three knife angles (30, 60 and 90°) and three harvest period at (15th November, 30th November and 15th December) compared with the traditional harvesting methods at 30th November. The twenty flowers were harvested in each treatment with three replicates.

4-Measurements

To determine the specification of the equipment:

a-The sepals length and thickness, fruit length and diameter ad neck diameter were measured by using the digital vernier caliper with an accuracy of ± 0.05 mm. then the plant length was measured by the tape meter 5 m with an accuracy 0.001 m.

b-The flower nick tensile force and the sepal shear force (N) were measured by using a digital force gauge with an accuracy of ± 0.01 N.

c-The sepal moisture content percentage was calculated on a wet basis using the ASAE (1983) method.

To evaluate the mechanical harvest and the Karkadi yield compared with the traditional harvesting method (y hand) the mass of Karkadi flower, fruit and sepals by using the digital balance with an accuracy of ± 0.01 g, the number of flowers/plant, yield of fresh sepals per fed.

$$\text{Increment yield} = \frac{\text{Machanical harvestig yield} - \text{handing yield}}{\text{Mechanical harvesting yield kg/fed}} \times 100$$

and percentage of fruit quality calculated by

$$\textit{Fruit quality} = \frac{\textit{Hale harvestig fruit}}{\textit{Whole fruit}} \times 100$$

were determined.

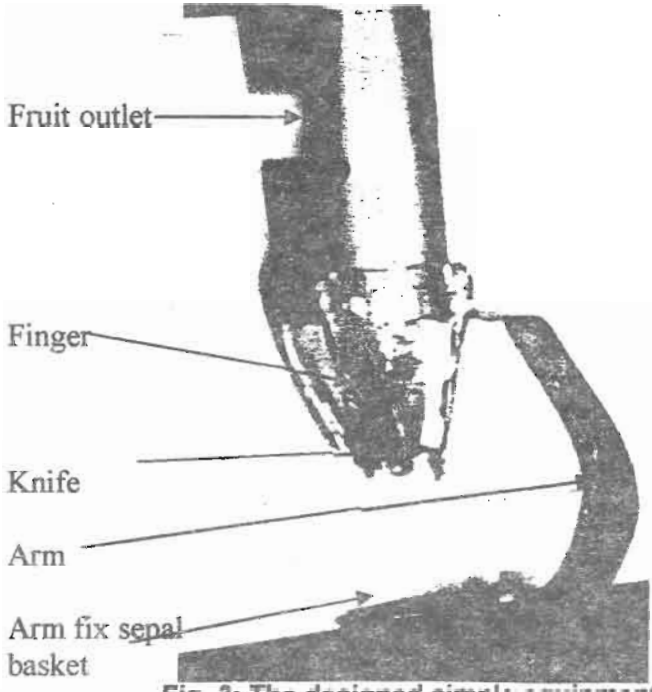


Fig. 3: The designed simple equipment.

Table 1: Some characteristics of Karkadi plant and its flower.

Items	Specifications		
Karkadi species	Light red-I	Dark red	Light red-II
Plant length, m	2.103	2.240	1.230
Flower shape			
Sepal thickness, mm	2.8	3.0	5.0
Sepals moisture content, %	89.3	88.2	87.4
Neck diameter, mm	5.4	6.1	4.3

D_n = Neck diameter
B_c = calyx base
W_f = Flower width
D_f = Fruit diameter
L_f = Fruit length
L_s = Sepal length

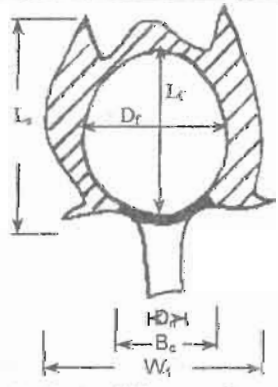


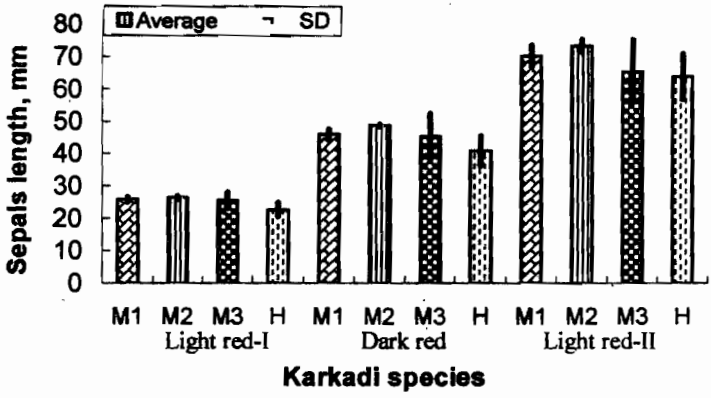
Fig. 4: Karkadi flower dimensions.

RESULTS AND DISCUSSIONS

1- The specifications of the Karkadi flower

The sepals length and fruits length and diameter were measured to estimate the dimensions of effective harvesting part of the manual equipment. Fig (5) shows the relationship between sepal length and Karkadi species at different harvesting period compared with the traditional method.

From the figure, the highest lengh of Karkadi sepal obtained at harvest time 30 Novemer for the three Karkadi species. While, the lowest obtaied at the traditioal harvesting method. Then the figure cleared that the highest sepal length was 73.45 ± 0.197 mm for light red-II at the second harvesting period (30th Nov.), while the lowest length was 22.65 ± 0.218 mm for the light red-I at the manual harvesting method.



M1, M2, M3 = mechanical harvesting periods at 15th Nov., 30th Nov., 15th Dec. resp. H = Harvest by handing

Fig. 5: The average and standard diviation of sepal length via Karkadi species at different harvesting period compared with the traditional method of harvest.

From Fig. (5) the sepal length at the harvest period 15th December were decreased compared with the period 30 November. This results may be due to the small size flower (un-complete ripe flowers) may occur on the plant at the last harvesting period.

Fig. (6) illustrates the fruit dimensions (length and diameter) via the Karkadi species. The figure cleared that there are no differences between the lengths of fruit species. The highest fruit length was 41.85 ± 1.08 mm of light red-II and the lowest was 26.38 ± 1.48 mm of dark red. The same previous effect results cleared in the fruit diameter. The figure shows the highest diameter was 19.39 ± 0.14 mm and the lowest was 16.22 ± 0.13 mm of the light red-II and light red-I respectively.

From Fig. (6) the differences in the fruits dimensions (length and diameter) show the fruit length increases of 38.50, 53.09 and 52.81 % from the fruit diameter for the Karkadi species light red-I, dark red and light red-II respectively.

The fruit the shear force and the tensile force of flower sepal and fruit were measured. Table (2) shows the tensile force of the flower neck at the different knives used. The data cleared that the highest tensile force was 101.3 N of light

red-I at knives angle 90°, and the lowest was 29.00 N of light red-II at knives angle 60°. Also, the highest shear force of sepal was 5.87 N at dark red and the lowest was 4.94 N at the light red-II.

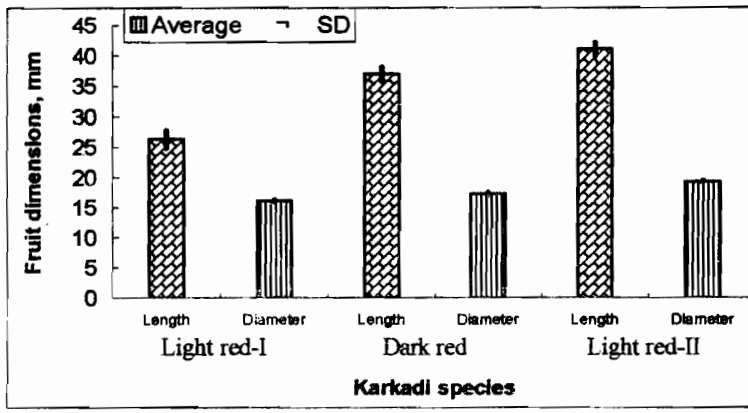


Fig 6: The fruit dimensions via the Karkadi species.

Table 2: the force required to separate the ripe sepals and to cut the fruit.

Karkadi species / Flower part	Knives angle degree	Light red-I	Dark red	Light red-II
Sepal shear force, N	-	5.0±0.05	5.9±0.51	4.9±0.66
Neck tensile force, N	30	71.3±3.87	82.9±3.58	50.4±3.42
	60	37.2±1.52	54.9±1.32	29.5±1.64
	90	90.5±4.48	101.3±5.74	70.2±3.91

2- The harvesting methods performance

To evaluate the harvesting methods the fruit quality, the mass of flower, fruit and sepal were identified. Also, determined the number of flower/plant and the yield of fresh sepals.

The quality of the harvest fruit shows in Fig. (7). The maximum fruit quality was recorded at the knives angle 60° for all Karkadi species. The highest harvesting efficiency was 98 % at knives angle of 60° and light red-II While the lowest at the knives angle of 90° for all Karkadi species. This result may be due to the knives with 90° cause a fruit damage that is may effect on the seed component quality.

Fig. (8) illustrate that the average of flower mass via Karkadi species at different harvesting period compared with the traditional method. The figure cleared that the highest flower mass was 12.955 ± 0.45 g for the light red-II at the second harvesting period (30th Nov.), while the lowest was 8.26 ± 1.62 g for the light red-I at the manual harvesting method.

Table (3) shows that the mass of fruit and sepal for the flower. The data cleared that the high value of the mass of fruit and sepal were 5.360 ± 0.23 g and 7.595 ± 0.26 g respectively for light red-II at the second harvesting period (30th Nov.). Also, the corresponding lowest values were 3.580 and 4.68 g respectively for light red-I at manual harvesting method.

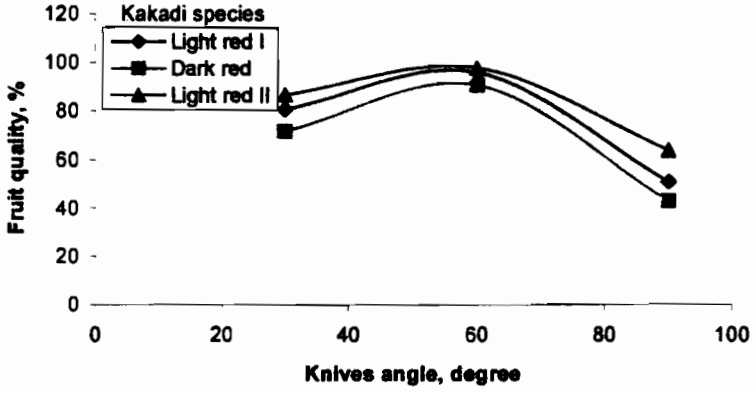
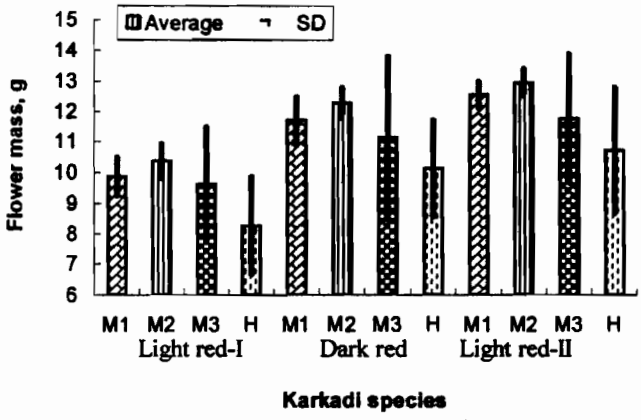


Fig. 7: The quality of the harvest fruit.



M1, M2, M3 = mechanical harvesting periods at 15th Nov., 30th Nov., 15th Dec. resp. H = Harvest by handing

Fig. 8: The average of flower mass via Karkadi species at different harvesting period compared with the traditional method

Table 3: The mass of fruit and sepal for the flower.

Harvest methods	Fruit mass, g			Sepal mass, g		
	Light red-I	Dark red	Light red-II	Light red-I	Dark red	Light red-II
Harvest at 15th Nov.	4.125	5.07	5.41	5.75	6.67	7.15
Harvest at 30th Nov.	4.355	5.29	5.36	6.03	7.00	7.60
Harvest at 15th Dec.	4.02	4.75	4.88	5.59	6.40	6.89
Handling harvest at 30th Nov.	3.58	4.48	4.61	4.68	5.66	6.11

Fig (9) clear the number of flowers/plant. The figure shows the high value of the average number of flowers/plant of 221.6 ± 10.15; 142.3 ± 3.77 and 166.2 ± 9.86 respectively at light I, dark red and light red-II.

Fig (10) shows the increment yield from the manual harvesting method versus the harvesting period at the three species of Karkadi. The figure shows the increment were 18.54; 22.32 and 16.28 % for the light red-I at the harvesting period 15th Nov, 30th Nov and 15th Dec respectively.

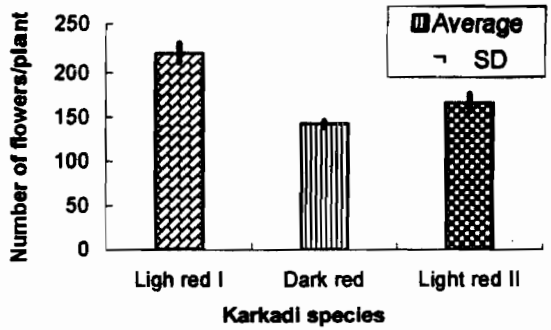


Fig. 9: Number of flowers/plant

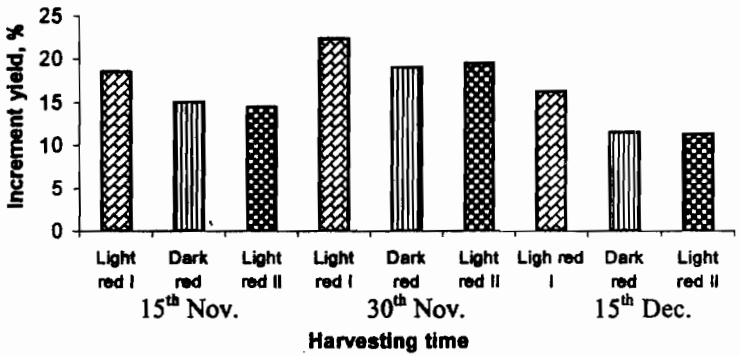


Fig. 10: The increment yield from the manual harvesting method.

Generally, the obtained results clear that the harvest period is the useful effect on the sepals yield, quality and the fruit as a by-product. Therefore the use of manual equipment is the benefit of the yield quality, quantity/time, maximize the income of yield/area and harvesting cost compared with the hand harvesting method.

Conclusions

The investigated manual equipment to harvest the Karkadi recorded the highest yield (22.32 %), quality (clean) and lowest cost (less about 500 LE) of Karkadi sepals and fruit compared with the hand harvesting method. From the obtained result, the average of Karkadi flower specification are sepal length of 73.4 mm, fruit length of 41.09 mm, fruit diameter of 19.39 mm, neck tensile force of 101.3 N and sepal shear force of 5.87 N. Then the optimum kife angle is 60° and the optimum harvesting method using the manual equipment at a periodically harvesting time.

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متطلبات الحصاد الآلى لأزهار الكركديه

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نبات الكركديه من أقدم النباتات فى مصر حيث يتميز بأهميته الإقتصادية من الناحية الغذائية والطبية والصناعية. والجزء الإقتصادى المعروف فى هذا النبات هو السبلات. إلا أن بذور الكركديه والتى تستخدم حتى الآن كتقاوي ذات قيمة غذائية عالية حيث تحتوى على ٢٠% زيت (Komarov, 1968). ويتم حصاد الكركديه حتى الآن فى معظم دول العالم يدويا حيث يتم قطف السبلات بعد حصاد النبات عند نضج معظم الأزهار وقبل تفتح الثمار (الكبسولات). إلا أن هذه الطريقة للحصاد تهدر محصول السبلات وتعرضه للتلوث مما يقلل من قيمته الإقتصادية.

لذا فإن هذا البحث يهدف إلى تصميم آلة يدوية تقوم بحصاد الأزهار بمكونيها (السبلات والثمار) فى الحقل مع المحافظة على نظافتهما حيث يستقبل كل منهما فى سلة خاصة به.

وقد إحتوت متغيرات الدراسة على ثلاث زوايا لقطع الثمار (٣٠، ٦٠، ٩٠ درجة)، ثلاث أصناف مختلفة من الكركديه (أحمر فاتح-١، أحمر غامق، أحمر فاتح-١١) لنوع صباحية ١٧، وثلاث فترات زمنية للحصاد لضمان إكتمال نمو الأزهار (تبدأ بعد ٢٠ يوم من تكون الثمار) (١٥ نوفمبر، ٣٠ نوفمبر، ١٥ ديسمبر والحصاد اليدوى فى ٣٠ نوفمبر). وقد تم قياس بعض الخصائص للنبات (الطول) والأزهار (طول السبلات، طول وقطر الثمار، مقاومة الشد للثمار، مقاومة القص للسبلات) كما تم تقييم طريقة الحصاد عن طريق تحديد جودة الثمار الناتجة، وزن الأزهار والثمار والسبلات، عدد الأزهار على النبات، محصول السبلات للفدان. وكانت أهم النتائج:

نتج من التجارب أن أطول سبلات ٧٣,٤ مم ، وأطول ثمار ٤١,٠٩ مم وأكبر قطر للثمرة ١٩,٣٩ مم فى صنف الكركديه أحمر فاتح-١١، فى حين كانت أكبر قوة لنزع الثمار ١٠١,٣ نيوتن عند زاوية سكين ٩٠ درجة، وأكبر قوة لقص السبلات ٥,٨٧ نيوتن فى صنف الكركديه أحمر غامق.

ومن خلال تقييم طريقة الحصاد أمكن التوصل إلى أن أفضل جودة للثمار الناتجة (غير مصابه) ٩٨% مع صنف الكركديه أحمر فاتح-١١، فى حين كان أكبر وزن لأزهار وثمار وسبلات الكركديه ١٢,٩٦، ٥,٣٦، ٧,٦٠ جرام على التوالى مع نفس الصنف السابق. كما أعطى صنف الكركديه أحمر فاتح-١ أكبر عدد للأزهار على النبات ٢٢١,٦، كما وصل أعلى محصول السبلات للفدان إلى ٥٣٤٠,٥٦ كجم سبلات طازجة أى بزيادة مقدارها ٢٢,٣٢ % مقارنة بالنظام التقليدى للحصاد.

ويوصى البحث بإمكانية إستخدام الآلة اليدوية مع إستخدام سلاح القطع بزاوية ٦٠ درجة على أن يتم حصاد الأزهار على فترات زمنية مما يتيح فرصة لإتمام نضج الأزهار وبالتالى زيادة العائد المحصولى لوحدة المساحة.