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Manish Kumar
Nalanda college of Horticulture. Noorsarai, Bihar Agricultural University, Sabour Bhagalpur, Bihar, India

Vishal Kumar
Nalanda college of Horticulture. Noorsarai, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Radhey shyam
Nalanda college of Horticulture. Noorsarai, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Correspondence
Manish Kumar
Nalanda college of Horticulture. Noorsarai, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Design and development of a mechanical makhana Harvester

Manish Kumar, Vishal Kumar and Radhey shyam

Abstract
The currently available technology of Makhana harvesting is not only indigenous and manual but also cumbersome and painstaking A mechanical makhana harvester was designed to facilitate makhana harvesting. to growing farmers. Different engineering properties were determined for designing and development of mechanized harvesting equipment. The seed kernel sphericity showed that the makhana kernel was almost sphereical. The mechanized harvesting equipment consisted of three major components, namely main mud pump with semi-open impeller, sieve unit and operator unit. The mechanical makhana harvester was found to be efficient in the harvesting process of seed from makhana fields. Seeds harvesting by mechanical harvester was 15.8 per cent higher than the manual harvesting as well as 2.8 per cent lower cost of harvesting. Three persons are required for the smooth operation of the makhana harvester, one for moving suction pipe at bottom of growing field, one for pump operation and one for separating makhana seeds from the sieve.

Keywords: Makhana, Harvester, Sphericity

Introduction
Makhana, *Euryale ferox* is considered a potential aquatic cash crop in India particularly in Bihar. Other than India, this unique product is grown in China, Nepal and Bangladesh. Edible part of makhana contains 12.8 per cent moisture, 9.7 percent protein, 0.1 per cent fat, 0.5 per cent minerals, 76.9 per cent carbohydrates, and 1.4 mg/100 g of carotene. Calorific analysis gives a value of 362 kcal/100 g for raw Makhana and 328 kcal/100 g for popped Makhana (Jha and Patil, 2009). Thus, the calorific value of Makhana compares well with staple food materials such as wheat, rice, etc. Makhana is considered superior to dry fruits such as almonds, walnut, coconut and cashew nut in terms of sugar, protein, and ascorbic acid and phenol content (Jha and Prasad, 1996). The medicinal properties of Makhana are also well established at least in China where it has been made mandatory ingredient in baby foods. It has also significance with having natural precious medicinal values: the number of human ailments as respiratory, circulatory, digestive, renal, and reproductive system may get cured after regular makhana consumption. Ayurveda mentions it to have spermatogenic and aphrodisiac properties.

Bihar accounts for more than 85 percent of the makhana produced in the country. Northern part of Bihar, constituting districts of Madhubani, Darbhanga, Sitamarhi, Saharsha, Katihar, Purnia, Supaul, Kishanganj and Araria, is agro climatically suitable for makhana cultivation. Makhana is a aquatic plant and flowers in month of April- may. Flower stay afloat for two days thereafter submerge inside water. Fruiting begins by mid of May and each plant bears around 10-20 fruits which contains 40-70 seeds. On an average, a plant of makhana yields around 450-700 gm of seeds. Makhana fruits burst inside water during May-July and the seeds float in water for a day or two and then settle at the bottom of the pond. In local parlance, makhana seeds are called guri. After fruiting, the gigantic leaves are cut and thrown out or left to decay, which enriches the soil health through addition of organic nutrient. The scattered seeds at the bottom of the pond are collected manually during August - September. Harvesting of makhana seeds is done by diving deep inside the water. The process of collection is strenuous involving a thorough sweeping of the entire bottom floor of the water area. Sweeping of the floor, making heaps and their retrieval requires several dives inside the water that makes the job really painstaking. Yield of makhana varies normally from 1200 to 1500 kg per hectare. However in low depth water bodies yield varies from 1800-2200 kg per hectare.

Harvesting of Makhana is highly cumbersome, labour intensive and involve human drudgery while sweeping bottom of the water body for seed collection. It is followed by processing of raw seeds, which is equally painstaking activity. Fishermen community belonging to the weaker sections of the society is mainly involved in makhana sector.

The present work was undertaken with the following objectives to design of machine for Makhana harvesting and optimize the machine parameters for best field responses.

Materials and methodology

Some engineering properties of Makhana was determined. These properties play an important role in designing of the a machine. Sieve openings, shape and size and weight of makhana seeds are some of the important parameters that must be known for designing the harvester.

Geometric mean diameter

The geometric mean diameter, Dg of raw kernels were calculated from the geometrical dimensions by formula given by Mohsenin, 1980; Bahnasawy, 2007.

$$Dg = (L.W.T)^{1/3}$$

where,
L = Length in mm;
W = Width in mm;
T = Thickness in mm.
Both geometric and arithmetic mean diameter was expressed in mm.

Sphericity

Sphericity of raw kernels was calculated by the following relationship (Mohsenin, 1980).

$$\varphi = \frac{(L.W.T)^{1/3}}{L} = \frac{Dg}{L}$$

where,
Dg = Geometrical mean diameter (mm);
L = length in mm.

Thousand kernel weight

Thousand seed weight was determined by counting 100 popped kernels randomly and weighing them in an electronic balance (0.001) and then multiplied by 10 to give the mass of 1000 kernels. The results were expressed in gms.

Designing of mechanical harvester

Designing of mechanical harvester was conducted in the Department of Agricultural Engineering, BAU Sabour. A mud pump with semi-open impeller size (20 cm) was fitted on moving trolly was used to suck the makhana seed with mud from the bottom of field. Suction head (1.0 m), discharge head (0.25 m) were used to mud pump along with suction length (5 m). Wheel arrangements were made for transportation of pump from one place to another. Suitable sieve arrangement was made for sieving off the harvested makhana seeds from mud. The sieve arrangement was kept in such a place, so that pump discharge directly falls upon the sieves. This arrangement separates the makhana seeds from mud easily.The different capacity of mud pump with diesel engine i.e. 5, 8 and 10 HP capacity were tested on manually broadcasted makhana seeds (10 kg/100 m^2) for evaluating the performance of makhana seeds harvester. The performance was also evaluated at another field experimental site at BPSAC Farm, Punea, Bihar to find out the field performance. The natural grown makhana in the pond and at the time of harvesting experimental field were cleaned manually to remove all the debris of leaf and petioles and make the plot ready for testing. The field was divided into six parts each bearing an area of 500 m^2. Three parts covering an area of 1500 m^2 was used for testing the performance of the mechanical harvester while in the rest three parts manual harvesting was done. The experimental was conducted in triplicate and the mean value of the observation is being presented in the result.

Results and discussion

Engineering properties of makhana seeds

The Sphericity of makhana seed was 97.8 ± 1.46, which shows that it is almost sphere shaped. The average value of angle of repose of the makhana seed was found between 26.40° and 28.18° with average of 27.22° ± 0.89° (Table 1).
The spericity is a relevant tool in determining the shape of the kernels. This will actually be an indication of the way the makhana seed will behave on oscillating surfaces during harvesting (Altuntas and Yildiz, 2007). It was observed that the mean angle of repose is considerably lower than that reported for sesame seed as 32° by Tunde-Akintunde and Akintunde (2004), and mean angle of repose of pumpkin and watermelon (Altuntas 2008). The smoother outer surface and the shape of the seeds are apparently responsible for the values of repose angle, and thus the easiness of the seeds to slide on each other.

Performance evaluation of Makhana harvester

Among the three ranges of diesel engine with mud-pumps selected for their testing under field condition 10 HP pump was able to pump the mud along with makhana seeds in the field, which showed highest (98 per cent) seed harvesting efficiency (Table 2). Therefore, 10 HP diesel engine with mud-pumps was chosen, so as to minimize the time of harvesting as well as increase the work efficiently. Timely and early harvesting of makhana not only reduced the losses due to natural calamities but also vacant the field for timely sowing of next crop such as paddy and water chestnut etc. Thus it might be increase the cropping intensity and better utilization of available resources.
The details of comparative performance of mechanical and manual harvesting revealed that due to high speed of operation, an output as higher as 12.5 kg/hr was achieved which was 3.13 times more than that obtained with hand operation (4.0 kg/hr) (Table 3). The efficiency remained higher in case of machine operated. The total yield recovery of Makhana seed was 1714.3 kg/ha and 1985 kg/ha under manually harvesting and mechanical harvesting, respectively which showed 15. 8 percent more efficiency. The cost of harvesting operation was only Rs. 3645/ ha with mechanical harvester, which is 2.8 percent less than that mannual harvesting. The designed and developed mechanical makhana harvester performed well with high harvesting efficiency and harvesting ability.

Table 1: Physical properties of makhana seed kernel

Physical properties	No. of samples	Range	Average
Sphericity (φ)	50	95.25-95.9	97.8 ± 1.46
Test weight (1000 seed weight)	100	493.8-543.5	27.22 ± 0.89
Angle of repose (θ), degree	5	26.40-28.18	11.25 ± 1.83

Table 2: Seed recovery (%) of the harvester at different energy consumption level

Capacity of Diesel Pump	Seed Broadcast manually (Kg)	Seed recovery (Kg)	Seed recovery (%)	Time taken for harvesting (hr)
5 HP	10.0	8.7	87	2.0
8HP	10.0	9.5	95	1.5
10HP	10.0	9.8	98	1.2

Table 3: Comparative performance of mechanical and manual harvesting (Mean value).

Performance indicator	Manual (Man)	Mechanical harvester
Output (Average), kg/hr	4 kg/hr	12.6 kg/hr
No. of labour required	15	3
Time taken to one ha area (hours)	360 (15 days)	36
Labour charges/day (@ Rs 250)	3750	1125
Cost of machine (Rs)	Nil	32500
Fuel cost/ha @1.25 litre/hr	-	2520
Total yield recovery (kg/ha)	1714	1985
Cost of operation (Rs/ha)	3750	3645

Conclusion

The research findings are expected to help in developing a light weight mechanized harvester so that it can easily be fitted on water boat with wooden frame sieve. This result also revealed to reduce the cost of harvesting operation with better efficiency. As a result of this, the study is expected to promote mechanical harvesting for the benefit of the farmers.

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