



A Drone-Mounted Spring-Released Blade Launcher for Fall-Free Walnut Harvesting: Concept, Design Analysis and Feasibility Study

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Abstract

Walnut harvesting in Jammu and Kashmir still depends on workers who climb tall, seedling-origin trees and strike the fruiting branches with long sticks. Hospital studies and news reports describe a recurring seasonal pattern of falls, spinal and head trauma, and deaths. This paper proposes a low-cost alternative: a detachable payload of about 200 g that can be fitted to any multirotor able to carry that mass. The payload holds up to ten lightweight, blade-tipped bolts, each held by a spring-loaded cradle and released one at a time by a servo motor commanded from the flight controller. A bolt severs the thin stalk on which a walnut cluster hangs, so the fruit drops to a collection sheet below. We describe the mechanical layout, the release electronics, the control-software flow, a first-order energy and mass budget, and a safety framework. We also discuss, candidly, the limits of the concept: the very large number of cuts a single tree requires, the effect of cutting on next-season fruiting wood, and the need for tests on real walnut stalks. The aim is to give the community a documented starting point for removing people from the crown of the tree.

Keywords: walnut harvesting, occupational falls, unmanned aerial vehicle, agricultural drone, servo-actuated release, Jammu and Kashmir

Introduction

India's walnut crop is concentrated in the Himalayan belt. APEDA reports that Jammu and Kashmir holds the largest share of national walnut area and output, and it lists national production for 2023-24 at roughly 307 thousand tonnes from about 86 thousand hectares [1]. Much of this crop is still picked by hand in the way it has been for generations: a worker climbs, often without protective equipment, and beats the branches until the nuts drop.

The human cost is well documented. A study of 106 patients admitted to Government Medical College, Srinagar, after falls during the 2006 season recorded upper-limb, lower-limb, spinal, abdominal, head and chest injuries, with most injuries occurring during the harvest itself and mature trees described as reaching around 30 m [2]. A 2025 study covering 150 labourers in Kupwara and Ganderbal, together with records of 95 workers treated at SKIMS Soura, identified falls from height as the leading danger and reported that 25 of the 95 hospitalised workers died [3]. Press reports from the 2025 season described several deaths within a few weeks, including one in Tral in September [4], and local experts have called for safety nets, helmets and platforms [5]. Journalistic accounts further note that the harvest season brings dozens of fall cases per week to Valley hospitals [6].

Behind these figures lies a simple mechanical failure. Striking branches while standing on another branch moves the worker's centre of mass repeatedly, loads the supporting limb unevenly and can snap a weak stem. The most direct remedy is to stop sending people into the crown at all.

Drones are already used for tasks at height. This paper asks whether a very simple, cheap aerial device, rather than a complex robotic arm, can take over the highest-risk part of the harvest. Our contributions are: (i) a modular payload that fits any drone with about 200 g spare lifting capacity; (ii) a servo-and-spring release scheme integrated with the flight controller; (iii) a first-order analysis of mass, energy and flight time; and (iv) an explicit list of safety and feasibility limits.

2. Related Work

2.1 Fruit-picking drones

The best-known aerial harvesting system is that of Tevel Aerobotics. Its tethered flying robots are powered from a ground platform, use machine vision to identify ripe fruit, and detach it with a gripper or cutter [7][8]. A granted patent describes harvesting and thinning with aerial drones for orchards and greenhouses [9]. Trade reports describe trials of the same technology on citrus in Brazil, where a cutting head can replace the suction head so that the stem is severed and the fruit falls [10]. These systems are sophisticated and costly, and are designed around dwarfed orchard trees rather than 30 m seedling walnuts on steep terrain.

2.2 Drone-based pruning and cutting

Research on cutting from the air is mostly aimed at forestry and utility corridors. Patent literature describes drones carrying rotary knives, saws and scissors for tree trimming, and notes the risk of the tool snagging in foliage and endangering the aircraft [11][12]. A stereo-vision study for radiata pine proposes a drone that detects branches as thin as 5 mm and positions a pruning tool on them [13][14]. A UK distribution-network project is comparing drone-mounted cutters for work near power lines and reports that safety, aviation and tree-work rules have to be satisfied together [15]. A recent paper in the International Journal of Agricultural and Biological Engineering presents a UAV-carried tip-pruning device whose blade speed and flight speed were tuned by experiment [16]. A student project in Karnataka also explored a low-cost drone for fruit harvesting and pruning [17].

2.3 Gap

Existing aerial systems either carry a powered cutter that adds weight, power draw and snag risk, or require elaborate sensing and manipulation. We found no published design that uses small, expendable, spring-launched cutting bolts released one at a time from a light payload. That is the niche this paper examines. We did not systematically review post-harvest packaging and grading of walnuts; that literature should be added by the authors before submission (see Section 9).

3. Problem Definition and Requirements

1. Remove climbers from the crown. The worker stays on the ground.
2. Light payload. At most 200 g in total, including holder, servo, battery tap and ten bolts.
3. Platform independence. Mountable on any multirotor rated for that payload.
4. Selective, repeatable release. One bolt per command, with confirmation.
5. Remote operation. Commands from a laptop or phone ground-control program through the existing telemetry link.
6. Safety by design. Armed only on purpose, only inside a cleared zone.

4. System Design

4.1 Overall architecture

The system has four parts: the host multirotor; the launcher module; the control link; and the ground station. A collection sheet or net is laid beneath the crown to catch fallen nuts.

4.2 Bolt design

Each bolt is a short, light shaft carrying a small blade fixed horizontally at the leading end, so that its cutting edge meets the stalk across its width. With ten bolts sharing a 200 g allowance, and assuming roughly 100 g is available for bolts and 100 g for holder, servo and wiring, each bolt may weigh about 10 g. [TO BE MEASURED: final bolt mass, blade material, edge geometry.] Plastic or carbon-fibre shafts with a replaceable steel or ceramic blade are natural candidates. A soft or frangible tail is advisable so that falling bolts are less hazardous.

4.3 Launcher and release

Bolts sit in a magazine, either as a ring or as a short rack. A compression spring drives the forward bolt. A hobby servo holds a latch; when commanded it rotates, frees the bolt and then returns, while the next bolt is indexed forward. A single-servo design is lightest, though it needs a mechanical indexing step. A two-servo design (latch and indexer) is simpler to make reliable at the cost of a few extra grams.

4.4 Flight-controller integration

Most open flight-controller firmware lets a servo channel be mapped to a custom function and triggered from the ground station over a MAVLink-style telemetry link. In our concept the servo channel is mapped to the "fire" action, and a second channel is used as an arming switch. A command from the ground-control program, whether on a computer or a phone, raises the pulse width for a short fixed time and then releases it. The control software also keeps a counter of remaining bolts so the operator cannot command a release from an empty magazine.

4.5 Control flow

1. Operator clears the area and places the collection sheet.
2. Drone takes off with launcher disarmed.
3. Drone climbs to the target height and holds position near the cluster.
4. Operator arms the launcher and confirms the camera view.
5. Operator commands one release; the program logs time, GPS position and bolt number.
6. Drone repositions; steps 4-5 repeat until the magazine is empty.
7. Drone returns, launcher is disarmed, bolts are recovered and the magazine reloaded.

5. First-Order Analysis

All numbers below are illustrative design estimates, not measurements.

Mass budget. Launcher 200 g maximum. Ten bolts at about 10 g each leave about 100 g for structure, servo and wiring.

Launch energy. For a 10 g bolt leaving the cradle at speed v , kinetic energy is $E = \frac{1}{2}mv^2$. At 10 m/s this is 0.5 J, and at 15 m/s about 1.1 J. The spring must store this energy plus friction losses. The required spring constant follows from $E = \frac{1}{2}kx^2$ for a chosen compression x .

Recoil. Momentum conservation shows a 10 g bolt at 10 m/s imparts 0.1 N·s to the airframe. On a small multirotor this is a brief pitch disturbance that the flight controller must absorb; tests should confirm that attitude recovers quickly. [TO BE MEASURED.]

Cutting requirement. Whether 0.5-1 J suffices depends on the shear strength and diameter of the walnut stalk at harvest time, which we have not measured. A bench test with a load cell on freshly collected stalks is the first experiment needed. [TO BE MEASURED: stalk diameter and cutting energy.]

Endurance. The target of 40-50 minutes depends heavily on airframe, battery and payload, and should be checked against the manufacturer's rating with the payload fitted. [TO BE MEASURED.]

6. Safety Framework

Because the device releases hard-edged projectiles, safety is a design requirement, not an afterthought.

- Exclusion zone. No person inside the working area, including the area where bolts may land, while the launcher is armed.
- Two-step arming. Physical or software arming switch, separate from the fire command, with a clearly visible indicator.
- Direction control. Fire only upward or sideways into the crown, never toward people, buildings, roads or livestock; use a geofence to keep the drone within the orchard boundary.
- Low-energy design. Keep bolt mass and speed to the minimum that reliably cuts the stalk.
- Recovery. Count and retrieve all bolts after every flight.
- Fail-safe. Loss of link must disarm the launcher and trigger return-to-home.
- Regulation. Operations must follow India's Drone Rules, 2021, and any local airspace restrictions in Jammu and Kashmir. [Authors to verify current rules and obtain permissions before field work.]

7. Proposed Experimental Plan

1. Bench tests: stalk shear force; spring calibration; bolt speed with a chronograph or high-speed camera.
2. Ground tests: accuracy and cut success on tethered branches at several distances.
3. Hover tests: recoil effect on attitude; release reliability over 50 repeated cycles.
4. Orchard trials: cut success rate, cuts per minute, bolts lost or not recovered, nut damage, and time per tree compared with manual beating.
5. Outcome measures: success percentage, time per tree, battery changes per tree, nuts recovered, and any injuries (target: zero).

8. Discussion and Limitations

Scale. The key practical question is quantity. Local reporting cites an average yield of around 130 kg per tree [18]. Even if a cut drops an entire cluster, a mature tree has a very large number of clusters. At ten bolts per flight, many sorties and battery swaps could be needed per tree. The device may therefore be best suited to the highest, most dangerous parts of the crown, to be combined with ground-based methods for the lower branches, rather than replacing all manual work.

Tree health. Cutting the stalk is not the same as beating. Depending on where the cut falls, shoots that would bear fruit next season could be damaged. Horticultural advice should be sought, and cut position should be restricted to the fruit stalk itself.

Targeting. Without machine vision, accurate aim in dense foliage is hard. A first-person-view camera is a minimum; later versions could add computer vision as in the pruning work cited above [13][14][16].

Wind and terrain. Hillside orchards and gusts will limit useful flying hours.

Economics. A small payload on a common drone is intended to be far cheaper than commercial aerial harvesting platforms [7][8], but cost per kilogram of harvested walnuts has to be measured.

Complementary measures. Safety nets, protective gear and grafted, shorter trees are also recommended to reduce falls [2][5]. The proposed system is one layer of a wider solution.

9. Scope Note on Packaging

The title of the original project includes packaging. This draft concentrates on harvesting. Post-harvest operations (husk removal, drying, grading, packaging) need their own literature review and are left for the authors to add, ideally citing peer-reviewed horticultural and food-science work.

10. Conclusion

Falls from walnut trees remain a serious and recurring occupational hazard in Kashmir. We presented a simple drone payload concept, built around spring-loaded blade-tipped bolts released by a servo from the flight controller, intended to take people out of the tree. The mass, energy and safety analysis suggests the concept is plausible at a small scale, but its real value depends on bench and field data we have not yet collected: stalk cutting energy, aiming accuracy, recoil tolerance, and the number of cuts achievable per sortie. We hope this paper serves as a clear starting point for those experiments.

Declaration

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