Nat. Volatiles & Essent. Oils, 2021; 8(6): 1203-1212

Development Of Low Cost Miniature Weed Harvester To Control Water Hyacinth

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Abstract

Growth of aquatic weeds impose a big problem in tropical and subtropical zones, where warm weather supports profuse growth of aquatic plants. Today most of the irrigation projects reported to be unsympatheticaly affected by abundantly growing aquatic weeds as they block canals and thus reducing the water flow. Present method employed for the purpose of cleaning lakes is very expensive. Large harvesters are not suited for small lakes. This necessitates the miniature aquatic weed harvester that can remove the aquatic weeds easily and efficiently. The present work involves the preliminary study on aquatic weed harvester considering all engineering parameters. Especially space, power requirements and drive systems. CAD and FEA softwares are utilised to frame out the final design of miniature aquatic weed harvester. The final model is fabricated and tested to observe the feasibility and working conditions. The present harvester can work for one and half hours covering the distance up to 100 meters at a stretch at a maximum speed of 1.13 m/s.

Keywords: aquatic weed, finite element, peddle, cutter.

1.Introduction

Aquatic weeds are those unwanted plants which grow in water and complete their life cycle in water. Some aquatic plants are desirable as their presence reduces the global pollution, especially agricultural and industrial pollution. Allowing aquatic weeds to grow in a water bodies and then killing these weeds after a period of time, consequently releases nutrients back into the water may help in fish production. However, many aquatic plants are considered weeds when they deprive all facets of efficient use of water. Aquatic weed problem is a global one but more pronounced in warm environment. Their presence effects on the ecosystem through changing energy transformation and nutrient cycles [1]. In India large irrigation projects have been reported to be adversely affected by abundantly growing aquatic weeds. Aquatic weeds are mainly of three types. They are emergent weeds, floating weeds and submerged weeds. In turn floating weeds are classified as free floating and rooted floating weeds. And submerged weeds are classified as shallow water submerged weeds and deep water rooted submerged weeds.

Emergent weeds: These weeds grow in shallow water bodies and locations where there exit continuous water up and water down movements. Examples of emergent weeds are, places near canals, rivers, side-line of water bodies belongs to dams and partly in masonry dams, drainage ditches and water ponds near small villages. These weeds are also called as semi-aquatic weeds. Typical Cattail narrow and Cattail common are few examples.

Floating weeds: Floating weeds vary in size from single cell and up to large vascular plants. These weeds originate on the surface of large depths as well as shallow depths of water bodies. Usually floating weeds are found in continuous flowing canals, deep rivers, large tanks and ponds. Some of the weeds, freely float and grow high. While others, float on the water surface but attach down to soil at the bed of the water body. These variants may double their population in 5- 15 days, growing in a favourable temperature of 28^0C – 30^0 C [2]. Floating weeds are sub-classified into two groups. In and around Bangaluru, the kind of weed found in the lakes are Water Hyacinth and it is as shown in fig 1.

Fig.1. Picture of free floating weed , Water Hyacinth

Submerged weeds

Submerged weeds germinate, nurture and reproduce under the water surface. Whereas their roots and reproductive organs remain in the soil at the bottom of the water body. As these weeds are not visible on the surface, they damage the most by stopping the water flow. Most of these weeds are found in shallow and medium deep water bodies, continuous flowing canals and drainage ditches. Submerged weeds are classified further as, shallow water submerged weeds(Blue green algae and Musk grass) and Deep water submerged weeds (Hydrilla and Bladderwort).

Water is the basis of all life forms on this planet. Hence proper management of water from source to consumption is essential to endure the normal function of life. Management of water in canals, reservoirs and natural waterways are affected by the existence of submerged weeds. The area under small tanks and ponds is equally important due to the establishment of many small irrigation schemes and watershed management projects. For example, India has around 1.9 million hectors under water reservoirs , 1.2 million hectors under irrigation canals and nearly 2.2 million hectors under village ponds.

Aquatic weed (AW) growth control methods[3]:

At present there are few methods available to control the growth of AW. They are

1. Mechanical control methods
    a) Underwater cutters b) Harvesters
2. Biological control method
3. Chemical control methods
    a) Herbicides b) varying chemical nutrients

Mechanical control methods: This method primarily consists of removing the weeds physically from the water body. That is , removal of weeds could be done manually by hand , by using hand tools or machine power. This method modifies the environment by eradicating the weeds from the grass-root. For example, harvesters and weed cutters are used to control the submerged weeds found in the big canals and very large water bodies. Mechanical control methods as follows.

a) Underwater cutters: this is one of the mechanical control methods**,** that make use of cutters attached to a motor boat. Machine consists of high-pitched, sturdy cutter rods along with the reciprocating blades that glide against a fixed blade.
b) Harvester: is a machine that cut and removes the weeds from water body and transport these to nearby storage sheds. Harvesting speed for typical machines range from 1 to 1.44 km per hour [4]. Harvester equipped with belt and conveyor have noisy operation and comparatively consumes more power [5,6].Depending up on the type of equipment used, the plants are cut from five to ten feet below the water surface. Cut plants are removed from water bodies by a conveyor belt system and stored on the harvester or warehouses until disposal. In some cases, barge may be constituted near the harvesting area for storage purpose. Now a days disposed weeds are reused as landfills, used as compost or as bio fuels.

Mechanical control methods have many advantages, such as better manpower utilization, environmental friendly and gives the results immediately. Also there will be a less fortuitous of ecological shifts in the aquatic flora. Mechanical methods rarely reduce the nutrient of eutropic water bodies. This helps indirectly in reducing the weed population in future.

Biological control methods: This method makes use of organisms to control the wild growth of the aquatic weeds. The organisms that are used for biological control are insects, pathogens, nematodes parasitic and competing plants. Biological method is more complex as it requires, long term planning[7], multiple strategies and manoeuvring of cropping system to interact with the surroundings. This method make use of bio control agents, aquatic mammals rodents and fishes.

Chemical control methods: This method is easier, faster and in fact cheaper when compared to mechanical methods. Using herbicides, AW can be controlled successfully. Depending up on the type of weed flora and the habitat in which weeds grows, the time and application of suitable herbicides are decided. Disadvantage of this method is herbicides settle in water as residue and sometimes there usage is of no effect due to more water flow. A herbicide should have certain requirements to reduce the weed production. They are High degree of phytotoxicity to kill the weeds at faster rate. Chemical must be stable, as not to react with other constituents in the medium to form harmful substances. Chemical should dissipate from water immediately after the action on weeds. Chemical should be environmentally safe for humans, fish and other aquatic fauna.

Drawbacks: Aquatic weeds absorb large quantities of nutrients from the water bodies due to which fish production reduces. Dense growth of aquatic weeds may provide ideal habitat for the development of mosquitoes causing deceases such as malaria, encephalitis and filariasis. These weeds severely reduce the flow capacity of irrigation canals thereby reducing the on time delivery of water to the farmers field. Aquatic weeds may damage turbines, pumps and other machine parts of the thermal power stations and hydroelectric power stations that lead to scarcity of electricity.

Motivation

Technologies being currently employed for the purpose of cleaning lakes are very expensive. Large harvesters are not suited for small lakes, especially in country like India. Initial investment , operational and maintenance costs are high and thus cannot be supported very often by the local civic bodies. Also skill operators are essential for the smooth functioning of the machine.Therefore considering all these constraints, there is requirement of low cost, easy to operate miniature aquatic weed harvester for the purpose of reducing the weed production. This is the motivation behind the present project work.

2. Methodology

Design and fabrication have been carried out to realize the set objectives in this project work.

The steps followed in this study are as follows

1. Feasibility study have been carried out by considering design criteria and calculations and final model is generated using CAD software.
2. Finite element analysis is carried out to determine the stresses and deformations in the critical parts of the weed harvester.
3. Fabrication and testing of the prototype
4. Conclusion

3.Preliminary feasibility study:

Design of the basic model and further calculations involved have been carried out keeping in mind the capability of the harvester to operate independently. To design a low cost easy to operate harvester prototype, some parameters are taken into consideration. They are weight, size, power requirements and drive system. The brief illustration of these parameters are as below.

Weight and size: one of the main objective of present work is to make a compact harvester as per as possible, without sacrificing the design and functionality aspect. This is possible , if the entire platform is made as light as possible. Hence a 20 litre plastic water cans are used as a floating platform. Advantage is cans can support larger loads and will not degrade over a period of time. Use of plastic cans , neither contaminate the water nor produce corrosion. These floats would entrap air, which enable them to float on water. Hence , the size of the current harvester is restricted to 6 sq.m in area and the kerb weight is to be around 12kg to 15kg.

Power requirements: Harvester of the modern day have power ratings in the range of about 30-100 HP. Being a working prototype model, a low power harvester is designed. The speed of the harvester is fixed to be in the range of 0.8 to 1.13 m/s . For this speed requirement, power of 1.5HP to 2HP would be sufficient to run the model.

Drive system: After the comparative study, paddle wheel mechanism with DC motors is selected as the drive system. Other options included conventional out board motors and fixed motors with rudder for steering.

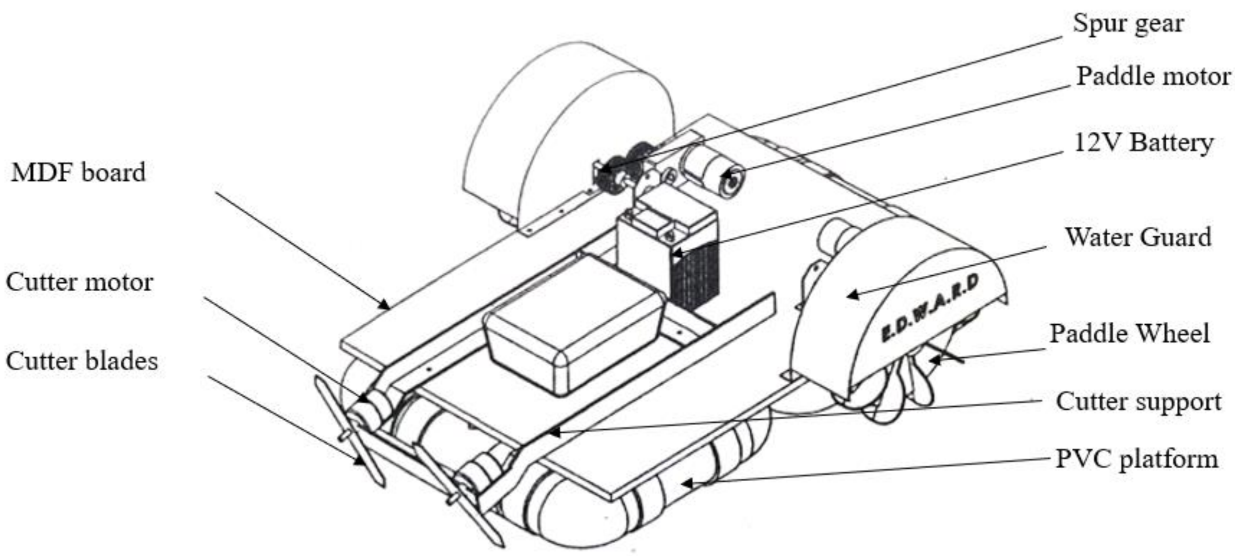


Fig.2. CAD of aquatic weed harvester

The main parts of the present harvester are; paddle motor, cutter motor, PVC platform, cutter support, cutter blades, 12V battery, paddle wheels, spur gear, water guard and components assembly. Detailed calculations have been carried out to ascertain operating parameters of the parts of a full working model. Theoretically calculated power value is compared with the power-speed graph [8] and thus power and speed of the motor is decided. Accordingly 1.5HP, DC motor is selected to match with the speed and drag due to paddle requirement of the present model.

The length 560mm and 35mm diameter of the main drive shaft from the motor is decided based on the maximum shear stress condition. Sleeve or muff coupling and journal bearings are selected based on the recommendation from design data hand book. Even though marine flange coupling can be a one more option, sleeve coupling have an added advantage. That is, there is no clearance issues between the shaft and platform and since the shafts are not forged into the flanges, a simple sleeve coupling is finally selected.

Selection of oil: choice of lubricating oil is based on working temperature of 60-70^0 C and possible friction at the journal bearings. Based on the recommended viscosity, power loss due to friction is calculated. And as power loss due to friction found to be very small, no lubricating oil is selected.

After the preliminary feasibility study, a CAD of the prototype is prepared and it is as shown in Fig.2.

4. Finite element analysis:

FEA is a numerical technique of finding approximate solutions to many engineering problems. Reason to resort to this approach is to verify whether critical components of the full scale harvester are capable of withstanding the stresses induced during the operation. This method helps to detect the formation of maximum stress as well as maximum deformation in the critical components. Because the failure of the components takes place at the place of maximum stresses. Two critical components are selected for the FEA, they are cutter support and cutter blades. Analysis is carried out using the Solid edge and ANSYS softwares.

4.1 Cutter support:

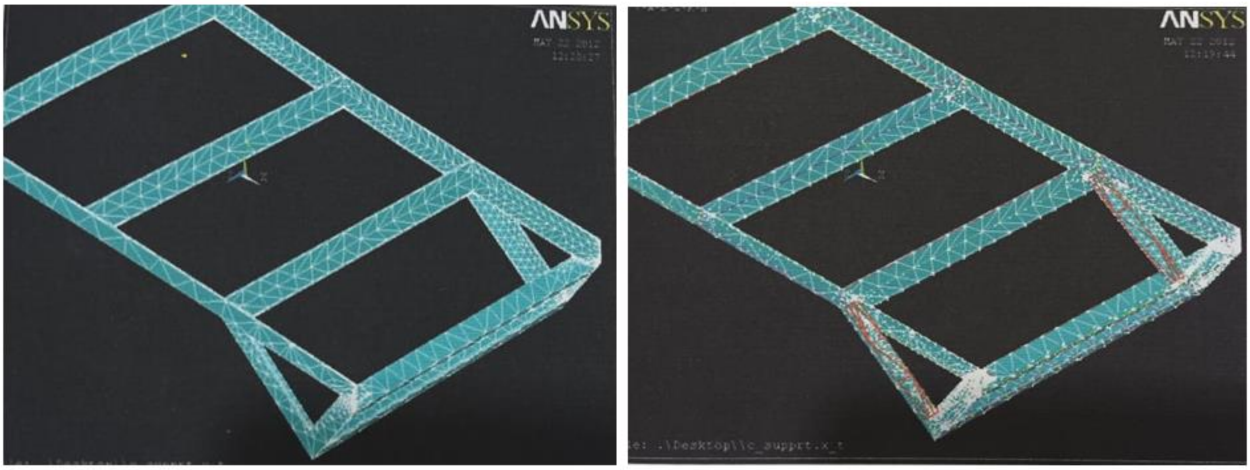
The main function of this component is to support the weight of the two cutter motors and also to absorb the vibrations induced during the actual cutting operation. Mild steel cutter support is mounted to MDF board with the screws. It is intended to take both axial and bending loads. The steps followed in the finite element analysis are as below.

Step 1. Part drawing created by the Solid edge software is imported to the ANSYS platform using the parasolid format.

Step 2.Using the extrusion option , volume of the part is created.In finite element analysis, pre-processor step, involves the preparation of nodal coordinates, finite elements creation, material selection, boundary conditions and loading.

Step 3. Material properties are assigned using the material model icon available in the software. Structural linear elastic with isotropic behaviour is selected, with modulus of elasticity 2.06 x 10^5 MPa and Poisson's ratio 0.3 are defined.

Step 4. For discretization, element size equals to 1 is selected. Entire volume is free meshed using the Brick node 45 element and it is as shown in Fig 3a.. Size of the mesh effectsthe outcome of the software and also the computation time [9].

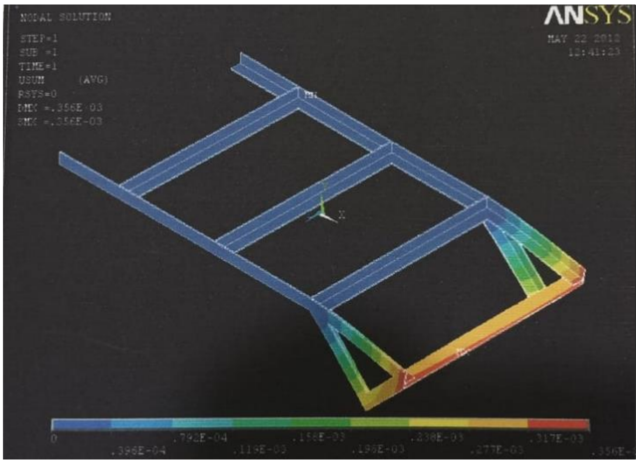


a b

Fig. 3 a cutter support is meshed **Fig. 3 b cutter support is constrained and loaded**

Step 5. After meshing operation, boundary condition is defined as the last step in pre-processor. Boundary conditions and loads define the relationship between the component and the surrounding environment. Structural displacement of nodes around the screws of the cutter support are set to zero so that all the degrees of freedom are constrained.Loads are applied in the form of uniform pressure acting on the three faces of cutter support. Total drag force per unit area of the harvester is calculated and applied at the pre-determined area as shown in Fig 3b.

Step 6. Important step in FEA is to get the solution of the assigned problem. This can be done by choosing the solver in the software. On submitting the command, solution procedure ends and software is ready to handle the post-processing operation.



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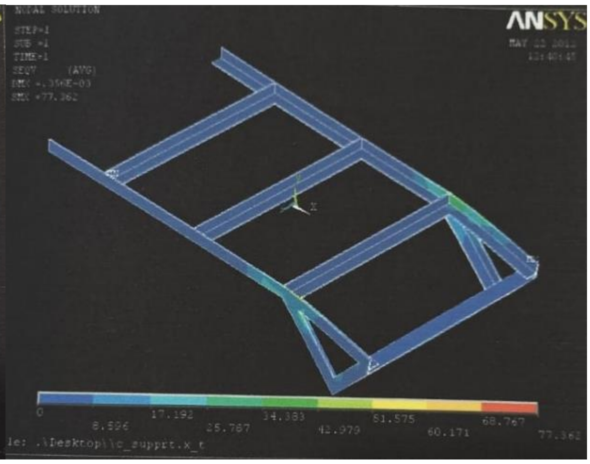

b

Fig.4 a Finite element deformation **Fig.4 b Finite element stress distribution**

Step 7. General post-processing operation: post-processing is carried out to manipulate the results thus obtained in the previous step. Operation includes computing unknown secondary or derived variables from the primary field variables and visualizing results graphically. Contour nodal solutions are obtained from the plot result option. The von Mises stress distribution in the critical area is highlighted and the same is saved for further study. Fig.4a and Fig.4b gives the FEA outcomes.A maximum stress of 77.362MPa is found at the T-junction of the cutter support. As this stress is far less than the internal resistance of mild steel, the support is capable of handling loads and vibrations. Maximum deformation is 0.356 x10^{-3} mm and is at the bottom part of the support. But this deformation is also very small enough and can be neglected.

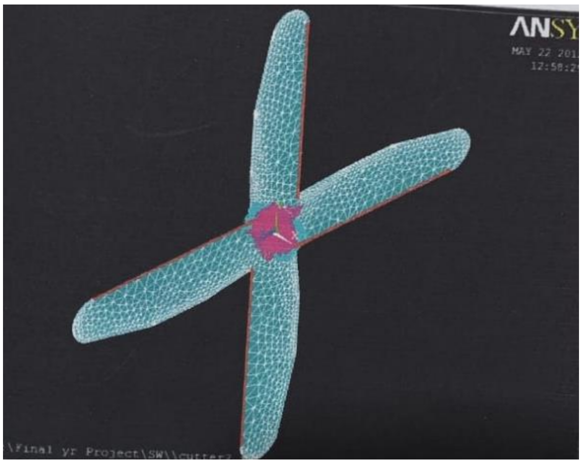

Fig .5 Cutter blade constrain and loading

4.2 Cutter blades:

Cutter blades are designed based on the yield strength of aquatic weeds [10]. Cutter blades are intended to take torsional loads due to rotation with respect to the centre of the blade. The same finite element procedure is repeated in this case also. All the degrees of freedom around the centre of the blade are constrained. Point load is applied tangential to the blade at the cutting edges as edges of the blade are involved in cutting of weeds. Fig 5 shows the body constraints and loading of the cutter blades.

After solving and following the general post processing deformation and stress contour is obtained as shown in Fig 6.

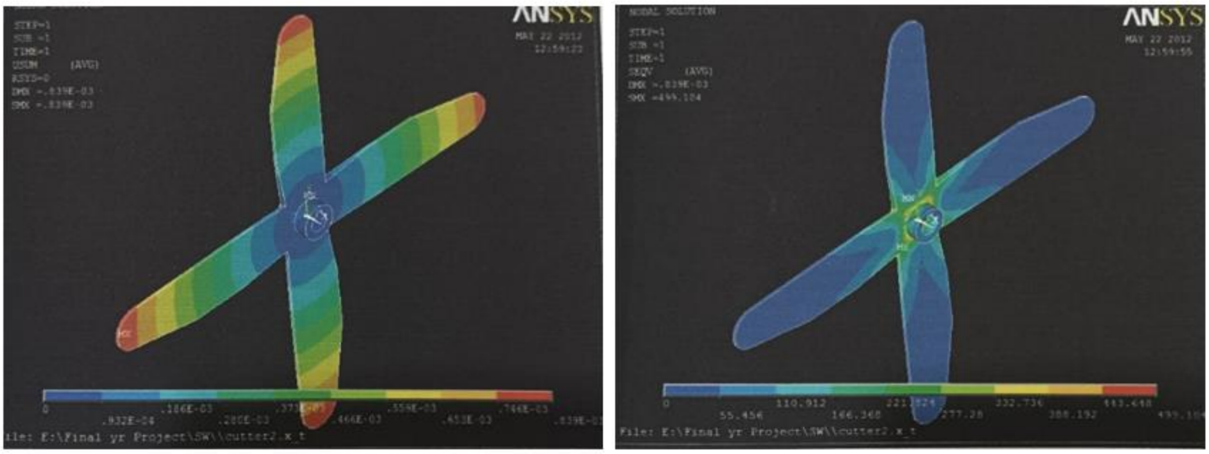

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Fig.6 a Finite element deformation of blades **Fig.6 b Finite element stress distribution around the blades**

A maximum stress of 499.104 MPa is found around the cutter blade centre and is as shown in Fig.6a. As this stress is very high, instead of Mild steel, high strength materials like, steel 1045 is recommended. Ultimate stretching force required for aquatic weeds is 15.6 N – 20.1 N[8]. Maximum deformation is 0.839 x10^{-3} mm and is at the edges of the blade as shown in Fig 6b. But this deformation is very small enough and can be neglected.

5. Construction and testing of Prototype

To move the platform forward, reverse, right and left, electronic speed -direction control (ESC) and radio frequency wireless control are incorporated. An ECS is an electronic circuit that helps to vary the electric motor speed and its direction. This circuit board is often used with electrically powered radio controlled models to control the brushless motors. This capability is used in the present model to control the direction achieved by the differential speed of the two motors. In this case the speed is set by Pulse Width Modulation. Other important parts are programmable microcontroller, IC drivers, RF control and power source.

Initially, a platform or hull is created using 2.5 inch PVC pipes and 15 mm thickness MDF board. These pipes are interconnected by using cyanoacrylate adhesives and later pipes are attached to the Wooden board using the screws. MDF board is made water proof by enveloping the board with the plastic sheet and fixed with drawing pins. This platform is intended to take more than 7Kg weight. Later 194mm diameter two paddle wheels are mounted with steel shaft and nylon bearing bush. Cutter support of size 680 mm x 1300 mm is fabricated as per the CAD using Tungsten inert gas welding. Two cutter blades are then directly mounted on the motor shaft using metallic washers.Cutter support is mounted on the MDF board as shown in Fig.2. Transmission system consists of two spur gears of same module are mounted on the motor shaft with paddle wheels. Other mountings such as battery, water guards and electronic module are then fixed suitably. The prototype is tested and noted the operating values as shown in table.1.

Table 1. Testing results

Sl.No	Parameters	Observed values
1	Harvester speed	0.2 – 0.3 acres per hour
2	Power-cutting	1hp
3	Maximum Velocity of travel	1.13 m/s
4	Cutter rotational speed	1500 rpm
5	Operating time	1- 1.5 hours
6	Range	100 meters

6. Conclusion

Objective of the present work is to create a working model of low cost and easy to operate in any environment.Miniature aquatic weed harvester is designed and fabricated. Concluding remarks of the present work is as below. Aquatic weeds can be removed out of ponds and tanks where humans can not reach.A multiple harvesters can be incorporated to clear the weeds , as these harvester costs less and also easy to maintain.

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