An agriculture vehicle has a mobile body and an arm. The arm has a first end supported upon the mobile body and a second end movable relative the mobile body. A cutting tool is operatively supported upon the second end of the arm. The cutting tool includes a blade configured for rotation.
FIG 13

Vacuum Outlet

Suction inlet

Water outlet

Water inlet

FIG 12

22
FRUIT TREE PRUNER AND HARVESTING MACHINE

CROSS-REFERENCE TO RELATED APPLICATIONS

None.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

No Federally sponsored Research or Development Grants, CRADAS, or other government funds have been utilized in developing this invention. Only the inventor’s funds have been applied to developing this invention and submitting the invention for a patent.

REFERENCE TO SEQUENCE LISTING, A TABLE, OR A COMPUTER PROGRAM LISTING COMPACT DISC APPENDIX

Not Applicable

BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to methods and apparatus for pruning of fruit bearing trees such as apples, pears, peaches, plums, apricots, cherries, avocados and citrus. And also, this invention relates to methods and apparatus for harvesting of fruit from fruit bearing trees such as apples, pears, peaches, plums, apricots, cherries, avocados and citrus.

The methods allow for individual removal of fruit that will meet the standards for the commercial fresh-market fruit requirements and will not require the fruit to be handled or removed by human hands. The harvesting process is automated and only requires the oversight and interactive control adjustments to the harvesting system.

This invention also relates to methods and apparatus for pruning of grape vines, and the harvesting of grapes that will meet the standards for the commercial fresh-market fruit requirements.

The pruning and harvesting of tree fruits for the premium fruit market has been a labor intensive process utilizing hand picking and careful handling of fruits. The proper pruning of the tree determines the access and location of the fruit that is harvested and are closely related. This pruner and harvester takes into consideration of the relationship between pruning and the position of fruit on a limb. Also many fruit trees are pruned during the winter season when the trees are free of leaves and allow the trunks and major branches of the tree to be determined as to their location in three-dimensional space. The fruit is located along these major branches and depending on the fruit, the location can be determined within inches. A graphical image of the tree is stored in a geographic information system identified by its global location. The harvester is mounted on a low motorized Self Propelled Vehicle (SPV) that moves between the tree rows. The SPV will have the appropriated number of robotic arms on each side. The harvester will harvest the fruit by cutting the fruit stem and the fruit will be removed by a vacuum hose that will handle the fruit without bruising or bumping the fruit against each other or against the branches of the trees. The fruit will be removed from the half of the tree nearest the fruit harvester. The fruit will be sorted and packaged to prevent further damage. The harvester will be driven between the rows of fruit trees during harvesting.

2. Description of Prior Art

A number of approaches have been taken to develop a mechanical tree pruner and tree topper. These systems mechanically chop or cut branches from the trees. Most of the systems also require hand pruning to prune the tree to its final configuration. The pruning and harvesting systems are not combined, but trellis systems have been utilized to make the manual pruning and manual harvesting more efficient. There are a number of mechanical pruning apparatus that use rotating cutter blades. An example is Rotary Blade Pruning Machine US. Pat. No. 6,250,056 B1 and references cited that prune or top the tree along a straight profile. The is no current pruning machine that can cut selected limbs and branches individually and collect an store the data of the pruned profile of the tree to be utilized to locate the fruit during harvesting.

Different approaches have been taken in recent years to develop harvesting machines that will quickly and efficiently remove fruit from trees in a condition that the fruit is suitable for market. Some success has been accomplished for very durable fruits and nuts, but unfortunately no approach has been successful for premium fruits grown for our commercial markets and our fresh markets. Examples of these are apples, pears, peaches, plums, apricots, cherries and citrus.

Shakers have been used with various catching apparatus to shake the tree trunk and catch the fruit that is dislodged. This has not been successful for premium commercial fruits, due to fruit bruising and damage from striking branches and limbs on the way down to the catch mechanism. There are a number of approaches to this effort including (Peterson, D., U.S. Pat. No. 4,606,179; Chiel and Zehavi, U.S. Pat. No. 5,816,037; Peterson and Kornecki, U.S. Pat. No. 4,860,529; Daniels, U.S. Pat. No. 5,946,896).

Another approach utilizes a branch or limb impactor to shake the individual limbs and catch the fruit on a soft conveyor. An example of this approach is shown in Peterson, D. L. and Wolford S. D., U.S. Pat. No. 6,442,920 B1.

Robotic Fruit Harvester, U.S. Pat. No. 4,532,757 use a commercial robot arm. Another Self Propelled Robotic Fresh Fruit Picker is shown in George Gray, U.S. Pat. No. 7,540,137 B2 which uses curved rigid tubes that are rotated to access the fruit and then convey the fruit down the tube. Louis L. Bernheim, George M Harris, U.S. Pat. No. 2,968,907 uses a pneumatic fruit gripper and straight tube to guide the fruit out of the tree, but it is a manual application and uses gravity to transfer the fruit. There has been limited success in some applications with some of the harvesters, but currently there is no commercial harvester being utilized for the fresh market fruits. There is no dual purpose pruner and harvester developed for the tree fruit production.

BRIEF SUMMARY OF THE INVENTION

The present invention relates to both tree pruning and fruit harvesting in that the functions are closely related in determining the location of the fruit on the tree.

For the pruning operation the pruner and harvester utilizes the Self Propelled Vehicle (SPV), the robotic arms, Global Positioning System (GPS) and Digital Imaging Systems (DIS). It also uses a heavier duty branch power cutter mounted on the end effector of the robotic arm. Each tree will be located by its GPS location, imaged from the machine and the machine will then prune the tree based on software pruning algorithms. The pruning algorithms will allow the trunk, a selected number of major branches, and a selected number
of fruit bearing limbs to remain as part of the tree. The remainder will be pruned from the tree. There are on the order of ten to fifteen major branches in most commercial fruit bearing trees today. The limbs will be pruned to allow the desired fruit spacing based on the fruit buds at the time of pruning. The tree will be pruned from the bottom up. The pruner will cut up the limbs until they fall to the ground. Once the tree is pruned the digital image of the tree is obtained and stored in a Geographic Information System (GIS) including the GPS global location as the identifier of the tree, and the GPS location of the machine. This will be key information that will be utilized by the harvester during the harvesting phase.

[0017] For the fruit harvesting operation the pruner and harvester utilizes the SPV, the robotic arms, GPS, GIS, and DIS that are utilized during the pruning operation. During fruit harvesting the pruner and harvester also uses a power stem cutter, a fruit catcher, a vacuum hose mounted on the end effectors of the robotic arm, a fruit collector system, and a Radar Ranging System (RRS) to locate the trunk and major branches. The location of the fruit and the order of picking will be predetermined based on the barren tree image at pruning that is stored in the GIS data base. Between pruning and harvesting, the picking algorithms for each tree will be generated utilizing a computer program that will build a 3-D stick image of each fruit tree. A 3-D profile for the tree half facing the harvester is generated, and picking algorithms are generated that will move the end effector along the limbs and branches and utilize the imaging system on the end effector to home in on the fruit to cut the stems. The fruit catcher will be held just under the fruit and when the fruit stem is cut the fruit will drop a very short distance and directed into the vacuum hose that will suck the fruit into the fruit collector. The fruit collector will catch the fruit and convey each piece of fruit to the fruit handling system, which will pack the fruit in fruit bins or fruit trays that will be placed on pallets.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0018] FIG. 1 is a perspective view of the pruner and harvester configured for harvesting.
[0019] FIG. 2 is a perspective view of the pruner and harvester configured for pruning
[0020] FIG. 3 is a front view of the pruner and harvester.
[0021] FIG. 4 is a side view of the pruner and harvester.
[0022] FIG. 5 is a top view of the pruner and harvester.
[0023] FIG. 6 is a detailed side view of the tree pruner end effector.
[0024] FIG. 7 is a detailed bottom view of the tree pruner end effector.
[0025] FIG. 8 is a detailed top view of the tree pruner end effector.
[0026] FIG. 9 is a detailed side view of the stem cutter and fruit catcher end effector.
[0027] FIG. 10 is a detailed bottom view of the stem cutter.
[0028] FIG. 11 is a detailed top view of the stem cutter.
[0029] FIG. 12 is a top view of the fruit collector.
[0030] FIG. 13 is a side view of the fruit collector.
[0031] FIG. 14 is a detail view of the Stem Cutter Shear Blade.
[0032] FIG. 15 is a detail view of the Stem Cutter Knife blade.
[0033] FIG. 16 is a detail view of the Pruning Shear Blade.
[0034] FIG. 17 is a detail view of the Pruner Knife Blade.
[0035] FIG. 18 is a depiction of the the 3-D stick image of 1/5 of the fruit tree.

DETAILED DESCRIPTION OF THE INVENTION

[0036] The present invention relates to fruit harvesting generally as configured in the FIG. 1 indicated as 1 and relates to tree pruning generally and configured in FIG. 2 indicated as 2. The fruit pruner and harvester machine is propelled through the orchard on a Self-Propelled Vehicle (SPV) is generally indicated as 3. The SPV consists of a structural frame 4, hydrostatic drives 5, low profile wheels 6, operator platform 7, motor and hydrostatic transmission 8, and electrical generator 9. These items are generally commercially available.

The SPV can be provided with self-leveling options that will keep the frame level for orchards on hill sides.

[0037] The robotic arms are shown in FIG. 1 through FIG. 5 and are indicated as forward arm 10, middle arm 11, and rear arm 12. There are six robotic arms two each of 10, 11, and 12 shown in these figures, but the number of arms may be varied depending on the type of fruit and picking rate desired. The arms are powered by hydraulic cylinders 13 and Computer Based Control System (CBCS) indicated as 14. The hydraulics can also be switched to manual and operated by the operator utilizing the joystick 15.

[0038] The Global Positioning System Guidance System (GPS) is indicated as 16 (FIG. 4) with the GPS antenna 17 (FIG. 4) mounted on top of the SPV frame to get a clear view of the sky. The GPS Guidance System locates the SPV at all times and drives the SPV on a centerline between the two tree rows, and provides a reference for referencing the data received from the Digital Imaging System (DIS) 18 (FIG. 4); Radar Ranging System (RRS) 18f (FIG. 4); and the CBCS 14 (FIG. 4).

[0039] A DIS cameras, indicated as 18a,b,c,d, (FIG. 5) provide dual images of the tree and references the images to their GPS location.

[0040] The RRS is indicated as 18e,f, (FIG. 4) measures the distance to the tree trunks, and major branches, and then the distance is referenced to the GPS location of the SPV.

[0041] All of these sensing systems are utilized in the tree pruning process and the fruit harvesting process. There are two duplicate systems one on the right side and one on the left side of the SPV that are mirror-imaged and each system operates independent of the other system. The speed of the machine is controlled by the operator.

[0042] The tree pruning process is described in detail with the machine setup in the pruning configuration as shown in FIG. 2. The SPV 3 is fitted with the larger Power Pruning Assembly 26 on the robotic arms 10, 11, and 12. The fruit catcher 20 and fruit vacuum hoses 21 are removed.

[0043] The operator uses the GPS 16 to align the machine to the center of two tree rows, or in the case of an edge row one sets the distance of the machine from the tree row. The operator initializes each of the robotic arms 10, 11, 12 to the start pruning position. The operator will then locate the first tree trunk on each side of the SPV 3 by guiding the most forward right robotic arm 10 until the end effector just touches the trunk of the first tree. The operator will do this task by operating the joystick 15. Then the operator will locate the second tree on the left side of the SPV 3 by guiding the most forward robotic arm 10 until the end effector just touches the trunk of the second tree. Note: the left side robotic arms are staggered ahead of the right side robotic arms on the machine. Once the
machine is aligned and initialized the operator the checks that all interlocks are good and selects the auto-pruning operation.

[0044] The CBCS 14 FIG. 2 will start pruning algorithms with the selection of an auto-pruning operation. The front robotic arms 10 will first make several passes using the Power Pruner Assembly 26 FIG. 2 to clear all limbs below the lower profile set for the trees. The DIS cameras 18a, b, c, d (FIG. 5) will process a number of dual digital images of the tree, and the superimposition of these images starting at the trunk will provide the data to develop a vector-based-stick-image of the tree trunk, limbs, and branches. The vector-based-image is represented by the image provided in FIG. 13. The CBCS 14 (FIG. 5) will be assigned a profile algorithm that will consist of about one-third of the tree to each robotic arm. The front robotic arm 10 will be assigned a profile for the lower one-third of the tree, the middle robotic arm 11 will be assigned a profile for the middle one-third of the tree, and the rear robotic arm 12 will be assigned a profile for the top one-third of the tree, and the top profile. The DIS 18 will be imaging the tree as it is pruned with the DIS cameras 18a, b, c, d (FIG. 5). The tubular paths around the stick images of the tree branches represent the exclusion areas for the pruning profiles for the half of the tree being pruned depicted in FIG. 13. When the rear robotic arm 12 completes its pruning profile, the rear DIS camera 18e will store and identify the final pruning image. This image data is stored in the GIS database so the data can be retrieved based on the location of the tree. The process is continued to the next tree in the row when the front robotic arm 10 completes running the profile assigned to it, and continues by pruning all limbs below the lower profile set for the trees. The process repeats itself for the next tree in each row as described above.

[0045] The fruit harvesting process is described in detail with the machine setup in the fruit harvesting configuration as shown in FIG. 1. The SPV 3 is fitted with the smaller Stem Cutting Assembly 19 on the robotic arms 10, 11, and 12. The fruit catcher 20 (FIG. 7) and fruit vacuum hoes 21 (FIG. 7) will also be installed. The fruit vacuum hose will be attached to the fruit collector 22 (FIG. 4). The air flow for the vacuum is provided by the blower 32 (FIG. 4) which creates a vacuum over the water in the fruit collectors 22 (FIG. 4).

[0046] The time between the pruning and harvesting is utilized to process the pruned tree images; generate a vector stick image of the tree trunk, major branches, and limbs; and generate an algorithm for locating the fruit in the tree based on the knowledge that the fruit sets on buds from the previous year. The computation time for generating the Pick Path Algorithm for the robotic arms 10, 11, 12 will not impact the harvesting speed since it can be completed between pruning time and harvest time. The algorithm will consist of a specific pick path for each robot arm 10, 11, 12, respectively, with the stem cutter assembly 19 (FIG. 1) attached. The Pick Path Algorithm will be generated and stored in the GIS database and will be downloaded to the harvester for each tree in the orchard at the time it is harvested. Each tree will be identified by the GPS location of the tree trunk.

[0047] The operator will use the GPS 16 (FIG. 1) to align the machine to the center line of two tree rows, in the case of an edge row set the distance of the machine from the tree row based on the stored coordinates that were collected during the pruning process above. The operator will then initialize each of the robotic arms 10, 11, 12 to the start harvesting position. The operator will do this task by operating the joy stick 15 (FIG. 1). Once the machine is aligned and initialized, the operator checks that all interlocks are good and selects the auto-harvesting operation.

[0048] The CBCS 14 (FIG. 1) will start harvesting algorithms with the selection of auto-harvesting operation. The front robotic arm 10 will in general harvest the lower limbs of the tree, the middle arm 11 will harvest the middle limbs of the tree, and the back robotic arm 12 will harvest the top limbs of the tree.

[0049] Once the stem cutter 19 (FIG. 1, FIG. 9) is positioned to the Pick Path Algorithm location, then a second algorithm is run that finds the closest fruit and cuts the stems using the DIS camera 18g, h, j (FIG. 9) mounted on the stem cutter assembly 19 (FIG. 9). When the DIS 18 (FIG. 4) detects the fruit the stem is cut the second algorithm turns control back to the Pick Path Algorithm. When the stem of the fruit is cut, the fruit falls a short distance to the fruit catcher 20 (FIG. 9), the air flowing in the vacuum hose 21 (FIG. 9), and moves the fruit individually to the fruit collector 22 (FIG. 4). The set of algorithms continue until the assigned pick path is completed for the robotic arm assigned to a tree. The arm then initializes on the trunk of the next tree to be harvested and the process repeats itself. The fruit collector 22 (FIG. 4) absorbs the energy of the fruit moving through the vacuum hose 21 (FIG. 1) by dropping the fruit into flowing water. The fruit handling system 23 (FIG. 4) uses water to wash the fruit and move the fruit to the elevator 24 (FIG. 4). As the fruit moves up the elevator 24 (FIG. 4) air is blown over the fruit to dry the surface water on the fruit. The elevator raises the fruit up to the bin loader 25 (FIG. 5) that gently places the fruit into the fruit bin 32 (FIG. 5) or trays.

[0050] The Stem Cutter 19 and Fruit Catcher 20 are detailed in FIG. 9, FIG. 10, and FIG. 11, and utilize synchronized counter-rotating Stem Cutter Shear Blade 29 (FIG. 14) and Stem Cutter Knife Blade 30 (FIG. 15). The blades are powered by a hydraulic motor 31 (FIG. 9). The fruit stem is captured between the counter-rotating cutter knife and the shear blade to provide for a clean cut and does not transfer energy to the fruit that could result in bruising. The stem cutter is shaped so that the fruit cannot be inserted into the cutting blades of the stem cutter.

[0051] The Power Pruner Assembly 26 is detailed in FIG. 6, FIG. 7, and FIG. 8, and also utilizes synchronized counter-rotating Pruning Shear Blade 27 (FIG. 16) and Pruning Knife Blade 28 (FIG. 17). The blades are powered by a hydraulic motor 31 (FIG. 6). The pruner operates in the same manner as the stem cutter, except the size is scaled up to cleanly cut the larger limbs.

1-10. (canceled)

11. An agriculture vehicle comprising:
a mobile body;
an arm comprising a first end supported upon the mobile body and a second end movable relative the mobile body; and
a cutting tool operatively supported upon the second end of the arm, the cutting tool comprising a blade configured for rotation.

12. The vehicle of claim 11 wherein the blade comprises a first blade, the cutting tool further comprising a second blade, the first blade configured for rotation in a first direction and the second blade configured for rotation in a second direction opposite to the first direction.
13. The vehicle of claim 11 wherein the blade comprises a central portion and cutting teeth extending radially outward from the central portion.

14. The vehicle of claim 11 further comprising a receptacle elevationally below and supported upon the cutting tool.

15. The vehicle of claim 11 wherein the cutting tool comprises a housing, and wherein only a portion of the blade is exposed from the housing.

16-28. (canceled)

29. The vehicle of claim 11 wherein the cutting tool comprises a camera.

30. The vehicle of claim 11 wherein the cutting tool comprises an elongated housing having an opening at one end, and wherein the blade is positioned at the one end of the elongated housing and configured to have only a portion of the blade exposed through the opening during rotation.

31. The vehicle of claim 11 wherein the blade comprises a first blade configured for rotation and a second blade configured for rotation.

32. The vehicle of claim 11 wherein the blade is powered by a hydraulic motor.

33. The vehicle of claim 11 wherein the blade comprises a knife blade configured for rotation and a shear blade configured for rotation, the knife and shear blades are configured for synchronized rotation.

34. The vehicle of claim 11 wherein the cutting tool comprises an elongated housing having a first end opposite a second end, and wherein the blade is positioned at the first end of the elongated housing and configured to have only a portion of the blade exposed through the opening during rotation, and wherein the second end has a hydraulic motor configured to drive the blade.

35. An agriculture vehicle comprising:
   a frame comprising a self-propelled system configured to move the frame on wheels;
   an arm comprising a first end supported upon the frame and a second end movable relative the frame; and
   a cutting tool operatively supported upon the second end of the arm, the cutting tool comprising a pair of blades spaced from each other and configured for rotation.

36. The vehicle of claim 35 further comprising a self-leveling option configured to maintain the frame in a level position during movement.

37. The vehicle of claim 35 further comprising a joystick in operationally coupled to the arm for manual operation.

38. The vehicle of claim 35 wherein the arm is powered by a hydraulic cylinder and a Computer Based Control System (CBCS).

39. An agriculture vehicle comprising:
   a frame comprising a Global Positioning System Guidance System configured to guide the frame during movement;
   an arm comprising a first end supported upon the frame and a second end movable relative the frame; and
   a cutting tool operatively supported upon the second end of the arm, the cutting tool comprising a pair of blades spaced from each other and configured for rotation.

40. The vehicle of claim 39 further comprising a receptacle elevationally below and supported upon the cutting tool.

41. The vehicle of claim 40 further comprising a hose extending between the receptacle and the frame.

* * * * *