

Application of Auto-steering Technology for Tree Planting¹

Reza Ehsani and Esa Ontermaa²

Setting up new orchards or planting new trees on existing beds is one of those orchard operations that have not yet been fully mechanized. Auto-steering technology can be used in conjunction with a tree planting unit to mechanize this operation and reduce tree planting costs.

Auto-steering technology is a revolutionary invention in agricultural machinery that completely changed the way we farm. This technology is currently being used very effectively for planting, spraying, and harvesting of row crops. It can lower costs and increase profits by improving efficiency and productivity of farm operations. Auto-steering guidance systems have the capability to steer a tractor across the field in a straight line or any predetermined track with an accuracy of up to two inches from the desired path. At the end of the field, the driver can steer the machine to the next pass where the auto-steering system takes over again. Even low-end systems today have a range of attractive options, and recent entries into the market have the capability to drive on a predetermined path that is programmed into the memory of an auto-steering computer unit.

The main components of an auto-steering system include a GPS receiver, the guidance computer units, a tilt sensor, and hydraulic valves or electrical actuators that work in parallel with the steering system. Auto-steering guidance systems can use one of two different GPS receivers for location position, either Real Time Kinematic GPS (RTK-GPS) or Differential Global Positioning System (DGPS). The auto-steering guidance systems with a DGPS receiver have pass-to-pass accuracies between 4 to 20 inches depending on the source of the differential signal. When using a DGPS receiver with auto-steering, the driver may experience the vehicle drifting from pass to pass over an extended period of time. A DGPS auto-steering system costs about \$3,000 to \$6,000. Using an RTK-GPS receiver, the auto-steering has the pass-to-pass accuracy of about 2 to 3 inches. An RTK-equipped auto-steering system costs about \$15,000 to \$25,000.

Auto-steering systems can be beneficial in two ways by 1) increasing productivity and efficiency of field operations and 2) facilitating the adoption of new and innovative field practices. Auto-steering can reduce operator fatigue and stress, which means an

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 2. Reza Ehsani, assistant professor, Citrus Research and Education Center -- Lake Alfred, Agricultural and Biological Engineering Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611; and Esa Ontermaa, Precision Agriculture Coordinator, Lykes Citrus Management Division, Lykes Brothers, Inc.

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operator can work longer hours and cover more acres. It is possible to drive at night or under conditions of poor visibility just as accurately as during the day. In addition, it is possible to employ less experienced operators and possibly increase operating speed.

In citrus operations, particularly in planting, the real power of an auto-steer system is its ability to follow a predetermined path much more accurately than an operator could. RTK auto-steering is ideal for planting trees. Currently, many growers and contractors still use a tape measure and sticks to mark the location of trees when establishing a new orchard. Tree planting consists of three different operations, including marking the location of a tree, digging holes in the ground, and planting the tree. According to recent UF reported estimates (www.crec.ifas.ufl.edu/extension/economics), the average cost of tree planting in the ridge area using conventional techniques is about \$2.39 per tree. Using a tractor with an auto-steering system and a tree planting unit can reduce this to a one pass operation at one-third of the cost. Moreover, with this system, it is possible to formalize a map with precise GPS coordinates of the rows and spacing of trees in advance, and then use the map to guide the tractor and planting crew in the field. The control computer will use the map to guide the tractor on the exact planned passes. Using this system, it is also possible to plant over existing beds. This could be particularly useful for replanting groves where trees were removed during the canker eradication program or where tree density has declined far enough to warrant replanting due to tristeza, citrus greening, or natural attrition. Figure 1 shows an RTK-GPS-based auto-steering and planter unit. Currently, several companies offer auto-steering systems, but to our knowledge, only one of them has the capability to follow a free-form predetermined path and has a built-in feature for tree planting. This built-in feature can provide a signal pulse during the pass that determines the location of the tree. The tree planting unit can use this pulse to plant the tree on the exact location.

Planting the trees in perfectly straight rows could be very useful for mechanical harvesting and can increase the efficiency of catch frame systems.



Figure 1. An RTK-GPS-based auto-steering with tree planting unit

Additionally, auto-steering technologies can be used for spraying and fertilizer applications, potentially increasing operator productivity. One thing to consider is that in the RTK-based auto-steering system, the GPS unit should have a clear view of the sky to receive the satellite signals; therefore, the GPS receiver may not function properly in orchards with tall trees.

Things to consider when choosing an auto-steering system for planting citrus trees

Accuracy is very critical for tree planting. Only the RTK-based auto-steering systems can provide the required accuracy. System drifts in excess of two inches subject young tree trunks to herbicide boom scuffing or over-run. In advanced high density plantings, fluctuations in DGPS signal can also impact caretaking and harvesting efficiencies. Planting on the top of existing beds could be more challenging; thus, auto-steering systems need to have some extra flexibility to be able to handle the task. In some cases, growers want to plant over existing beds, and these are not always perfect. For example, one end of the bed could be wider than the other end. Therefore, the system must be able to accept a free-form planting path where the trees can be planted so that the row shape best serves the operations and equipment. As an example, one may want to keep row distance standard on the tops of the beds to keep the tree rows from slipping too far into the furrow. This can allow any inaccuracies to fall on the swale side. Doing just the opposite may be necessary if the row distance in the swales is different from that of the bed tops and equipment configurations demand a minimum space on the swale side. So far only one system has been able to demonstrate this kind of free-form system, although others seem close to releasing similar systems. Most other systems allow

one to place a primary or first planting line, called an AB line, where needed and often in whatever shape is needed. Consecutive planting lines, however, are placed at a fixed off-set distance. In older bedded groves where distances change from bed to bed, the last row planted with this kind of system may be in the middle of the furrow.

It is very important that the auto-steering system used with the tree planting system is equipped with the tilt correction capability to avoid deviating from the desired planting path. When a tractor is operating on tilted ground, the GPS antenna installed on the top of the tractor cab will show a wrong location (Figure 3). New RTK auto-steering systems have the capability to sense the tilt and make corrections to account for the terrain.

Auto-steering systems clamping to the steering column and/or wheel cannot respond fast enough, partially due to inherent steering wheel play and partially due to slower response times. These delays increase drift and can be problematic in precision planting applications. It is better to purchase an auto-steering system that hooks directly to the tractor's steering hydraulics. Most new tractors either have an auto-steer readiness kit or offer it as an option, and the automated systems can be attached to the auto-steer readiness kit. For older tractors, the auto-steer manufacturers may offer a conversion kit that enables direct hydraulic steering control. Every tractor is different, so compatibility and kit availability should be verified first. Even with a new tractor, it is wise to verify that the intended auto-steering system is compatible with the tractor.

A word of caution is needed here. It may be that the tractor has what it takes to do the job and the selected system appears to be the perfect mate. But will the combination do what it needs to do? For example, gearing the tractor can become a problem if an intermediate speed between two gears is needed. This is especially true on the low end of the tractor speeds. To maximize power and optimize speed, continuous velocity transmission (CVT) or a track-equipped tractor may be necessary. The minimum speed for auto-steering systems varies from system to system with the lowest ones ranging from 0.5-1.0 mph. Below this threshold, the systems may

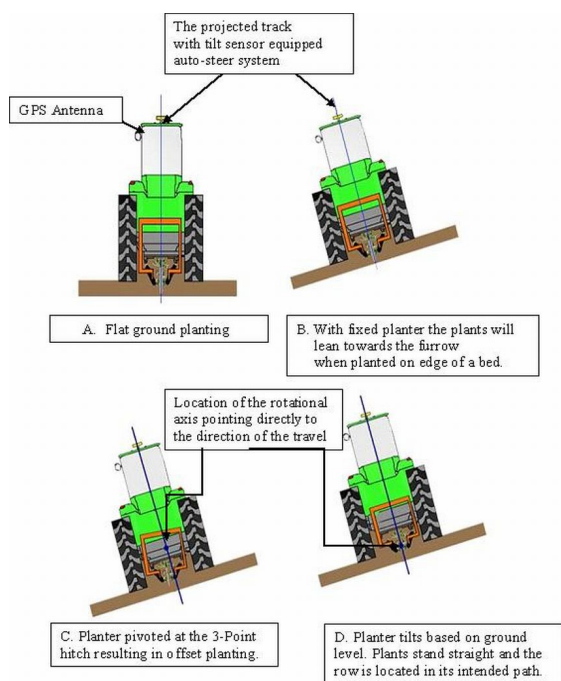
lose their ability to calculate a path or they lose their GPS fix. The ability of the system to read both GPS and GLONASS (Russian) satellites can be an advantage here. The higher the number of satellites available for the system, the less likely it is to lose the fix as the constellations pass over the work location.

Figure 2 shows the tree planting unit with the plants being fed to the unit by a human operator. For such units, going too fast reduces the time for the operator to feed the plant to the system. Human reaction time optimally varies between 0.15-0.20 seconds. It should also be considered that it takes 0.35 seconds for a transplant to drop 2.0 ft in a free fall into the hole. If the planter's closing wheels are too close, the plant may not have enough time to reach the bottom of the hole and the wheels may damage the roots. At 1.5 mph human planting capacity, reaction delay plus free fall time will offset the plants more than 1.0 ft from intended locations (Table 1). The best planting speed is about 0.5 mph. Some auto-steering units may not be able to guide well at such low speeds.



Figure 2. Tree planting unit attached to a tractor with RTK auto-steering system.

When automating operations, there is a tendency to worry about the electronics; however, the auto-steering system might be the easiest part of the entire system, once it has been decided exactly what the system is expected to do. Auto-steering systems have been used extensively for years in the Midwestern United States, and any problems initially found in the systems have long since been fixed. The implement, such as a tree planter, may actually be the more problematic element. There are no known commercial "citrus planters" on the market. A number of forestry equipment and apple industry applications are available, but most of them are built for flat land planting. Their performance is questionable in a slope of 4-8 degrees on the edge of an existing old or new



who are considering establishing high density citrus orchards. However, the commercially available tree planters need some modifications before they can be utilized in the field.

Figure 3. Schematic illustration of the tilt angle on plant positioning. A) Fixed planting implement works fine on flat ground. B) Same unit on the edge of the bed will cause the plants to tilt toward the furrow. C) Using 3-point hitch arms as rotational center will offset the planter, which makes the plant straight up but not at the desired location. D) Best results occur when the planter is a pull behind and can be tilted manually or hydraulically based on ground level.

bed. Further issues may surface if the same unit is to plant a high density planting that consists of more than two rows per bed. A tree leaning in an 8.0 degree angle toward the furrow or a row planted 4-10 inches off the intended track is not exactly what one expects from a system that may cost in excess of \$50,000. To avoid this, the planter must be able to tilt in a perpendicular plane to the direction of the travel, while the rotational axis, pointing to the direction of travel, must be located at the soil surface as illustrated in Figure 3. Using a planter that tilts at the level of the top arms of the 3-point hitch can be used as long as the offset between the actual path and where the planter places the row is considered in preparing the guidance maps.

A combination of the auto-steering and tree planting unit can potentially be a new, cost-effective alternative approach to planting new citrus trees. This method is particularly more beneficial for growers

Table 1. Examples of Equipment (EQ) speeds and their impact on planter movement and required plant counts per minute at various in-row distances.

Equipment ground speed		Time to travel 1.0 ft (s)	Plants required per minute at spacing of			
(mph)	(in/s)		6 ft Count	8 ft Count	10 ft Count	12 ft Count
0.5	8.8	1.36	7.33	5.50	4.40	3.67
1	17.6	0.68	14.67	11.00	8.80	7.33
1.5	26.4	0.45*	22.00	16.50	13.20	11.00
2	35.2	0.34*	29.33	22.00	17.60	14.67
*Exceeds estimated system limitations for human planting.						