VEGETATIVE PROPAGATION OF *CELTIS OCCIDENTALIS* L.

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Abstract.--Common hackberry (*Celtis occidentalis* L.), a member of the Ulmaceae, is an important specimen and shelter tree species in the northern great plains and has been considered a replacement for the besieged American elm. Improved selections and introduced cultivars are often difficult to vegetatively propagate. Vegetative methods investigated in this study included propagation by cuttings and grafts. Cutting methods included hardwood, softwood, etiolated and blanched stem cuttings as well as root cuttings with and without IBA application. Budding methods included chip, prong and T-budding. Grafting methods utilized bark, greenwood cleft, seedling cleft, side and whip and tongue grafting. Propagation by stem cuttings was generally unsuccessful despite supplemental application of IBA. The most successful vegetative propagation methods were root cuttings (5 cm long) from juvenile phase (2-yr-old) trees shallowly inserted into a peat-sand medium and side grafts utilizing parafilm wraps and a graft tent.

Additional keywords: Blanching, bleeding, budding, *Celtis laevigata*, *C. sinensis*, cuttings, desiccation, etiolation and grafting.

INTRODUCTION

Common hackberry, *Celtis occidentalis* L., is a temperate tree species which possesses cold hardiness into U.S.D.A. plant hardiness zone 2. As a member of the Ulmaceae, individual specimens may exhibit a nearly elm-like growth habit. It is immune to Dutch elm disease, possesses considerable drought tolerance and also exhibits lemon yellow fall color, unusual corky bark and attractive retentive pea-sized drupes. Witches' broom and nipple gall (twig and leaf galls) somewhat limit ornamental quality of the species. Nurserymen have noted resistance to both pest problems in natural hybrids of *Celtis occidentalis* and *C. laevigata* Willd. Two hybrid cultivars released into the nursery trade are *Celtis* 'Magnifica' and *C.* 'Prairie Pride' (Flemer n.d., Wandell n.d.).

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Unlike elm, which is relatively easy to vegetatively propagate, common hackberry and both of its hybrid cultivars are difficult to propagate by conventional means. There are numerous references on the vegetative propagation of Ulmus but literature on the vegetative propagation of Celtis is nearly non-existent. Several commercial nurseries have discontinued hybrid hackberry propagation by cuttings due to low success rates (Meyer 1983, Moller 1980, Wandell 1980, personal communications). Chip budding and side-grafting have met with limited success (Flemer, Wandell, personal communications). Several techniques of vegetative propagation were utilized in the present research with a goal of possible adaptation to commercial production (Redlin 1984).

LITERATURE

Cuttings

Literature on cutting propagation of Celtis is virtually nonexistent. A brief reference often cited states hackberry can be "propagated with cuttings of ripened wood" (Bailey 1920). IBA applica tion to extremely soft cuttings of common hackberry was of questionable benefit and a timed sequence of continuous humidification was essential to prevent desiccation of cuttings (Whitcomb 1981, personal communication).

Early flushing cuttings of Chinese hackberry, Celtis sinensis Pers., readily rooted when leaves were fully expanded (Lee 1983, personal communication). Tree to tree variation in rooting ability of cuttings from individual 25-year-old trees was noted.

Blanching means the exclusion of light from plant tissue after a period of exposure to light. Etiolation is the development of tissue in the complete absence of light. Accounts of utilizing either technique to modify stem cuttings of Celtis were not cited in the literature.

Lists of woody plant species propagated by root cuttings have been compiled (Donovan 1976). Ulmus is often propagated by root cuttings. Celtis is not known to be propagated from root cuttings although Pinchot (1907) stated "young trees of common hackberry have the ability to resprout from the root when cut down, though in older trees this rarely occurs."

Grafting

The few references to grafting hackberry, list basic methods but are not specific as to technique. Several propagation texts list Celtis as a genus that can be graft propagated by side or veneer grafting (Laurie and Chadwick 1931, Mahlstede and Haber 1957).

Graft incompatibility within the genus has not been reported in the literature even though initial correspondence with wholesale nurserymen indicated incompatibility as a possible reason for low field (fall) T-budding stands in the Celtis hybrid cultivars. Furthermore, McDaniel

(1964) reported that interspecific graft combinations were "perfectly compatible after 15 to 20 years." Subsequent communication with nur serymen indicated that low field T-bud stands could be caused by an insufficient level of bark slippage, i.e. inadequate cambial activity at the time of budding.

T-budding success of common hackberry selections on rootstocks of the species was found to be quite variable and ranged from 10 to 50% in three years of testing in Canada (Vanstone, Ronald and Marshall 1982). Research in England has shown that chip budding of Ulmus and several other woody genera resulted in increased stands of budded trees (Howard 1973). In chip budding, healing of the graft union, uniformity of growth, height growth, formation of lateral branches and winter survival were greater when compared with T-budded trees. Spring and summer chip budding have been recommended as a "satisfactory method" for the vegetative propagation of Celtis (McDaniel 1980, personal communication).

MATERIALS AND METHODS

In this research project, experimentation was done on the North Dakota State University campus using the facilities of the Department of Horticulture and Forestry from March 1981 through November 1983.

A randomized complete block design (RCBD) was used to test the effects of treatments of selected propagation techniques. Analysis of variance procedures were used to test the data for significance and Duncan's Multiple Range Test was used to identify significant differences at the 0.05 and 0.01 levels. Data were analyzed independently for each experiment using Statistical Analysis System (SAS).

Hardwood Cuttings

Prior to bud break, cutting wood was collected from several local tree sources and made into 1200 (10 cm long) hardwood cuttings. Cuttings were subjected to wounding and treatment with five second "quick dip" applications of four IBA concentrations to the basal 25 mm of each cutting. Concentrations were 0, 5000, 10000 and 15000 ppm indole-3-butyric acid (IBA) dissolved in 50% ethanol. Cuttings were inserted into two different media, i.e. sand and sand/sphagnum peat 50:50 V:V. Bottom heat of 21 to 24° C and an air temperature of 10 to 13° C was maintained.

Within two weeks of inserting the 1200 cuttings representing 48 treatments (25 cuttings per treatment), bud swelling occurred and the majority of cuttings produced 5 mm of shoot growth from the exposed bud. Shoots desiccated despite maintenance of a humid environment. Slight callusing was evident at the basal ends of cuttings but none of the cuttings rooted. This method was not pursued further.

Softwood Cuttings

Experimentation was done in three growing seasons using softwood cuttings from 10-, 15-, 25-, 30-, 45- and 70-year-old trees. Current growth was removed in May, June and July and made into 12 to 14 cm cuttings. Vertical wounds 25 mm in length were used in combination with IBA. Hormonal treatments included concentrations of IBA at 0, 1000, 2500, 4000, 5000 and 8000 ppm. Applications of naphthaleneacetic acid (NAA) at 3750 ppm and a combination of 2500 ppm IBA and 2500 ppm NAA were also used. All synthetic hormones were applied as three second quick dips in 50% ethanol to the basal 12 mm of cuttings. Several groups of cuttings were treated with kinetin (6-furfurylaminopurine) at 50 and 100 ppm. These foliar sprays were applied to drip point and allowed to surface dry at 20° C as a pretreatment with the intent of delaying senescence and/or preventing leaf drop. Cuttings were inserted into a rooting medium of Jiffy Mix/perlite (50:50; V:V) contained in cell packs and placed in a mist room with an automatic mist system regulated by a "sensitive balance" mist controller. This high humidity environment was maintained at an air temperature of 21 to 32° C.

Cuttings from Etiolated Shoots

In a preliminary experiment, seedling rootstocks were cut back to five cm and covered with damp sphagnum moss. The small number of succulent shoots that grew through this medium were removed as 12 cm cuttings. The basal ends of cuttings were examined and recut but not treated with synthetic hormone before cuttings were inserted into a flat of sand and placed under mist. Wilting did not occur as readily as typical softwood cuttings from more mature trees. All of these etiolated cuttings rooted within two weeks which spurred further interest in similar light exclusion techniques in softwood cutting propagation.

Blanched Versus Unblanched Cuttings

The basal leaves from the current growth of 10-yr-old windbreak trees were removed and the basal 5 cm of shoots was blanched by wrapping with squares of aluminum foil. Controls were unblanched stems. Shoots were removed as cuttings after 30 days. Visual comparisons showed that the basal region of controls was grey in color and crushed when bent to 90 degrees. The bases of blanched cuttings were beige to pale yellow and broke cleanly as a result of bending. Treatments given to both blanched and unblanched cuttings were four concentrations of IBA, i.e. 0, 1000, 4000 and 8000 ppm applied as quick dips.

There were no significant differences in rooting between blanched and unblanched cuttings which received various concentrations of IBA. This was interesting to note, since blanching often significantly increases the rooting response of cuttings of deciduous trees.

Softwood Cuttings from Potted Seedlings

Thirty six dormant potted seedling rootstocks were placed in a lathhouse and cut back to five cm. Shoot length was five to eight cm within two weeks and three groups of 18 rootstocks subsequently received different treatments. Shoots of the first group were blanched with a technique adapted from Munson (1982). The bases of shoots were covered with a mixture of sphagnum peat and sand (50:50; V:V) at weekly intervals until the blanching container was filled. The basal leaves of the second group of rootstocks were removed and the bases of stems were blanched by wrapping with aluminum foil at approximately two week intervals. The third (or control) group received no blanching or defoliation treatments. Shoots from all groups were cut flush from the rootstock stub and treated with IBA at 0, 1000, 4000 and 8000 ppm.

Root Cuttings

Two hundred seventy root cuttings 5 cm in length were made from seedling rootstocks. Neither exogenous auxin nor fungicide was applied. Cuttings were inserted into a medium of moist sand and peat; 1:1; V:V; with the proximal ends protruding above the medium. All root cuttings (except those of root cutting experiment 7) were collected in early spring from dormant plants. Seven additional root cutting experiments were done and statistically analyzed (Table 1). Individual tree selec tions were groups and tree ages were treatments with several replicates of each. Experiments 1, 2 and 3 involved no exogenous hormone application. Experiments 4, 5, 6 and 7 utilized treatments of IBA (Hormodin) at concentrations of 0, 1000, 4000 and 8000 ppm applied in talc to the distal 1.25 cm of each root cutting.

Table 1: Summary of Root Cutting Experiments.

Description of Experiment	Application of IBA
Experiment 1: Proximal ends of cuttings from 2-year-old trees were inserted at three different depths in the medium. Positioning of the proximal ends included 1.3 cm below, equal with the surface and 1.3 cm above the surface of the medium.	No
Experiment 2: Cuttings from three 10-year-old trees were collected to compare regenerative ability of trees of the same age from the same site in a windbreak.	No
Experiment 3: Root cutting regeneration from 2-, 10- and 75-year-old trees was compared. Groups were from different sites.	No
Experiment 4: Root cuttings from a two- and ten-year-old tree were compared.	Yes
Experiment 5: Root cuttings were taken from two 10-year-old trees from the same location as above.	Yes
Experiment 6: Root cuttings were taken from one 75-year-old tree.	Yes
Experiment 7: Root cuttings were taken in the fall from several two-year-old dormant unchilled common hackberry and American elm to determine if chilling was required for the development of shoots.	Yes

Cleft Grafting

Epicotyls of 10-day-old seedlings were removed directly above the cotyledons and the remainder of the stem was cleft with a razor blade. The terminal two cm of herbaceous shoots was removed from local trees. Scions were made by reducing the leaves and cutting the bases of scions into thin wedges. Cleft grafts were tied with soft cotton string and grafted seedlings were enclosed in shaded polyethylene bags.

Herbaceous scions from local tree sources were also cleft grafted onto the current growth (green wood) of 100 two-yr-old potted rootstocks. The scions and graft unions were covered with white polyethylene bags and supported by tying the rootstock stems to metal rods.

Whip and Tongue Grafting

Scions were whip grafted near the soil line of seedling rootstocks. Graft unions were wrapped with rubber electrician's tape and roots were slightly pruned to facilitate subsequent potting. Completed grafts were stored in polyethylene bags with damp cedar shavings at 24 to 27° C for three days to promote callus formation. Grafts were potted and placed into a mist room though not in direct contact with mist.

Bark Grafting

In an initial experiment, 50 actively growing potted seedling rootstocks exhibiting bark slippage were brought into the greenhouse and bark grafted. The lower part of each scion was wrapped with rubber electrician's tape to secure the scion and reduce desiccation.

This method of grafting resulted in excessive rootstock bleeding and sap was exuded from the tip of the exposed scion within 15 minutes of making each graft. Buds broke and a small amount of shoot growth developed but it soon became obvious that copious bleeding was occurring in the graft region. A dried chalky white exudate on the grafts was evident. Shoots collapsed and the result was no successful graft unions. Rootstock bleeding of Celtis was not referenced in the propagation literature (Hartmann and Kester 1983).

In the next experiment, 40 similar rootstocks were bark grafted and four different treatments to reduce bleeding (10 plants per treatment) were utilized. Scions were secured with conventional rubber budding strips and covered with a single layer of parafilm M® (American Can Co., Greenwich, CT 06830) which prevents moisture loss but allows gas exchange. Treatments included the following: small notches made below the graft area, retention of rootstock shoots and both notching and shoot retention. Controls were unnotched desuckered rootstocks.

Side Grafting

Since bleeding was a problem when grafting hackberry, side grafting was utilized which allows the rootstock to function "normally" during graft healing. Watering of rootstocks was reduced to prevent excessive bleeding.

The graft technique used was similar to the one described by Wells (1955) in the propagation of Japanese maples and fastigiate junipers. Rubber budding strips instead of cotton string were used to secure the scions to rootstocks in the side grafting experiments that follow:

Experiment 1. A small number of 1-yr-old rootstocks were utilized in an initial experiment. They were side grafted when shoot growth started and placed into a polyethylene "graft tent" which contained dampened sphagnum moss to provide supplemental humidity.

Experiment 2. Forty similar rootstocks were grafted later the same season. The graft regions of 20 grafted rootstocks were covered with grafting wax and the remaining 20 were uncovered. Both groups were placed in a graft tent.

Experiment 3. Ninety 2-yr-old rootstocks were lightly watered and allowed to break dormancy. Grafting with three local scion sources commenced when shoot growth was 20 cm. Grafts were placed on a bench in a high humidity greenhouse and covered with a piece of white polyethylene sheeting as a graft tent.

Experiment 4. Scions from three local sources and the cultivars 'Delta,' 'Magnifica' and 'Prairie Pride' were compared by grafting onto 108 rootstocks. Each of the six genotypes was a treatment.

Experiment 5. One hundred eight rootstocks of Celtis were grafted with three local sources of scion wood. Half of the graft unions were wrapped with parafilm and half were not wrapped. All grafted rootstocks were placed in a polyethylene tent.

Experiment 6. Seventy-two rootstocks were grafted with scions from a local 20-yr-old tree and the cultivars 'Magnifica' and 'Delta'. Half of the grafted plants were wrapped with parafilm, the other half was not and all were placed on an open greenhouse bench as a post-grafting environment.

T-Budding

A preliminary experiment resulted in a mean of 67% bud unions when slipping rootstocks were T-budded, wrapped with conventional rubber budding strips and headed back to the bud in two steps after T-bud healing had occurred.

Numerous T-budding techniques were investigated the following season in the three experiments utilizing a total of 288 rootstocks. Treatments included the following: forcing of budding wood, "wood in" vs. "wood out," binding treatments (conventional rubber budding strips vs. parafilm), conventional T budding vs. "prong" budding, additional wrapping vs. no wrapping and conventional T-budding vs. inverted T-budding.

Chip budding

One hundred potted foliated rootstocks which were not slipping were chip budded during the first week of September. All buds had a retained petiole but in some of the treatments the basal one-third of the leaf blade was also retained. Several treatments were used to bind graft unions (rubber electrician's tape vs. conventional rubber budding strips) and wrap graft unions (8 X 13 cm plastic wrap vs. no wrap). Chip budded rootstocks were placed into a polyethylene tent and dampened sphagnum moss was added for supplemental humidity.

The above experiment was repeated the following season but all binding was done with conventional rubber strips. The chip budded rootstocks were placed on an open bench in a 21 to 24° C greenhouse.

RESULTS

Softwood Cuttings

During three growing seasons utilizing various methods of softwood cutting propagation, rooting was found to be erratic and very low, usually less than 10%. Though hackberry cuttings were quickly collected and processed, some wilting occurred which may have decreased the ability of cuttings to root. Rooted cuttings grew weakly or did not continue shoot growth. Few survived the first dormant period when held in artificial cold storage at 1° C. The use of softwood cuttings did not appear to be a viable method when compared to other means of propagation.

Softwood Cuttings from Potted Seedlings

Significant differences occurred (P=0.01) when cuttings were collected from the three different groups of two-year-old rootstocks. Seventy percent of the peat/sand blanched cuttings rooted but none of the cuttings from the other groups rooted. IBA treatments were not significantly different.

Root Cuttings

Seventy percent (189 of 270) of the root cuttings from two-year-old seedlings produced plants. Newly developed root systems were extensive but shoot, growth was not vigorous.

Experiment 1: Results of root cuttings from seedlings showed that insertion depth is important. Table 2 shows that cuttings inserted with proximal ends 1.3 cm below the surface of the medium produced few plants (8%). Percentages dramatically increased as insertion depth decreased. Cuttings inserted with proximal surfaces flush with the media surface and 1.3 cm above the surface resulted in 50 and 100% regenerated plants, respectively.

Table 2. *Celtis occidentalis* : Insertion Depth of Root Cuttings

Experiment 1 - Treatments	Mean % Successful Propagules@
1. Proximal end 1.3 cm below surface	8 c
2. Proximal end flush with surface	50 b
3. Proximal end 1.3 cm above surface	100 a

@Treatments not followed by the same letter are significantly different at the 0.05 level as indicated by Duncan's Multiple Range Test.

Experiment 2: There were no significant differences in regeneration of root cuttings between trees of similar age growing at the same site. The mean of three ten-year-old trees was 31.6%.

Experiment 3: This experiment utilized root cuttings from trees of dramatically different ages growing on different sites. Table 3 shows that the success of root cuttings decreased as the age of the tree source increased.

Table 3. *Celtis occidentalis*: Age of Tree Source For Root Cuttings.

Experiment Treatment Groups	Mean % Successful Propagules@
1. Seedlings (2-year-old trees)	72 a
2. Windbreak (10-year-old trees)	28 ab
3. Specimen (75-year-old trees)	6 b

@Treatments not followed by the same letter are significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Experiment 4: Various treatment concentrations of IBA yielded no significant differences in regeneration, but the replicates which consisted of two differently aged trees (two- and ten-year-old) were significantly different (95.7% vs. 42.7%).

Experiment 5: Four treatment concentrations of IBA were utilized with two ten-yr-old trees of similar age and location. Neither replicates or treatments displayed significant differences in regenerative ability. The mean regeneration of groups was 41.5%.

Experiment 6: Treatments of different IBA concentrations did not yield significant differences in regeneration of root cuttings from a 75-year-old tree. Low percentages (<10%) were noted.

Experiment 7: This experiment utilized unchilled roots from dormant trees and was discontinued after six weeks. Despite what appeared to be favorable conditions for rooting, i.e., auxin pretreatment, bottom heat, adequate moisture and extended daylength, unchilled root cuttings of common hackberry and American elm failed to produce callus, buds or shoots when collected in the fall.

Cleft Grafting

The percent of successful seedling cleft graft unions was 30% in the first experiment and less than 10% in the second experiment. This method of propagation was discontinued due to the low success rates (attributed to susceptibility to fungal growth) and the considerable difficulty encountered in grafting the small succulent stems.

Only 6% of green wood grafts resulted in successful graft unions but all were characterized by increased thickening at the graft unions. The cause of this swelling is not definitely known although high temperatures and humidities in the post-graft environment may have promoted greater callus development.

Whip and Tongue Grafting

The mean percent of graft union success was 13.3% and resultant shoot growth was 15 cm in the first season. The lack of vigorous growth was attributed to inadequate establishment of the rootstocks. This was avoided in subsequent grafting and budding experiments by allowing a greater amount of time for rootstocks to be containerized before grafting.

Bark Grafting

No significant differences resulted between the four treatments in the second bark grafting experiment and treatment means of successful graft unions were from 10 to 30%. Due to excessive bleeding and subsequent graft failure, this method was discontinued even though it was relatively fast, easy and made efficient use of scion wood.

Side Grafting

Experiment 1. Five days after grafting, the exposed buds on a given scion began to develop into shoots. Approximately ten days after grafting, lower shoots were removed allowing one scion shoot to develop on each graft. Forty-two percent of the graft unions were successful.

Experiment 2. Seventy percent of the waxed grafts and 55% of unwaxed grafts were successful which indicated that additional prevention of desiccation of the graft union was beneficial.

Experiment 3. The means of successful graft unions using local scion sources were 100, 76.6 and 53.3%. A single scion shoot was allowed to develop from each successful graft and grafts were placed under 50% lath shade. The mean of first year growth was 46 cm.

Experiment 4. The treatment means of grafted plants were significantly different but this may have resulted from variable storage conditions for scion wood. The range of successful graft unions was 11.1 to 94.4% and the mean was 52%.

Experiment 5. Treatments were not significantly different. The mean of successful graft unions without parafilm was 66.6% compared to 90.7% for wrapped unions. Parafilm wraps may have been too thick and probably prevented bud expansion. Parafilm did not readily deteriorate under greenhouse conditions and it may be desirable to decrease the number of layers of wrap covering the scion and graft.

Experiment 6. Treatments were significantly different. The percentage of wrapped grafts was 41.6% but the unwrapped grafts was 0%.

<u>T-budding</u>

None of the treatments resulted in significant differences in bud union success. The range of percent T-bud take in the three experiments was 6-28%, 0-17% and 22-56%. The problems encountered were bleeding with resultant "flooding out" of the buds and a weakening of subsequent bud growth beneath wraps because parafilm deteriorated slowly under glass greenhouse conditions. Greater success may have resulted in the third experiment because rootstocks were slightly more foliated which reduced bleeding.

<u>Chip Budding</u>

During the three week graft healing period, nearly all of the chip buds with a retained portion of leaf blade were infected by an unidentified pink fungus. Mycelium progressed through the petiole and often killed the axillary buds on the chip bud plate. Only three chip buds of 100 attempts were successful and all of these were in the same treatment which was the following: scion wood from a 75-year-old tree, leaf portion retained on buds, bound with rubber electrician's tape and wrapped in polyethylene. Shoots from the few successful chip buds produced desirable whip-like growth which was straighter and more vigorous than shoot growth from T-buds.

All chip buds failed on the open bench in the second experiment and greenhouse chip budding was discontinued. Even though bark slippage is not required for chip budding, the timing of chip budding should be further investigated.

SUMMARY

Difficulties have existed in the vegetative propagation of _Celtis occidentalis_ and its hybrid clones. The lack of an effective vegetative propagation method has prevented widespread nursery production and therefore precluded the use of superior selections of hackberry for landscape use. During this research project, various vegetative propagation methods were investigated to determine a practical or commercially acceptable method of propagation. Impractical methods and/or those resulting in low percentages of propagules were discontinued after preliminary experiments. Methods yielding unacceptable responses included hardwood cuttings, softwood cuttings, cleft grafting of herbaceous seedlings, cleft grafting of green wood, whip and tongue grafting, bark grafting and chip budding.

Blanching stems of seedling hackberries with a peat and sand medium resulted in rooting of 70% of stem cuttings. Rooted cuttings from seedlings could be used as clonal rootstocks for further grafting studies.

Root cuttings taken from juvenile plants (2-yr-old seedlings) of common hackberry were found to have high regenerative ability. Serial propagation, i.e., taking cuttings from "younger and younger" propagules, has proven effective in the propagation of other woody genera. The utilization of root cuttings or other propagation methods which result in "own rooting" may therefore prove to be a viable means of commercially producing selected mature trees of common hackberry.

Rootstock bleeding inhibits graft healing in _Ulmus_ and other woody genera. Propagation literature makes no reference to bleeding in the genus _Celtis_. Bleeding adversely affected healing of hackberry graft and bud unions in this study.

First year growth rates of successful side grafts in this study were less than those indicated by wholesale nurserymen using field chip and T-budding. However, side grafting showed particular promise and is a potentially useful propagation method for the plant propagator. Successful side graft union percentages were often greater than 90% when utilizing a graft tent in a greenhouse. The use of parafilm in conjunction with side grafting may also yield high success rates without using graft tents or grafting waxes.

T-budding was found to result in intermediate success rates. This method appeared most successful when budding was done when rootstocks were in full leaf and exhibited less bleeding.

Further research could determine the optimum time and physiological condition of budwood and rootstocks for T-budding and/or chip budding in the greenhouse or field. Chip budding of hackberry could be further investigated due to the advantages obtained in _Ulmus_ and other deciduous tree genera.

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