Optimization of Planting Practices to Maximize Rubber Yield in *Taraxacum kok-saghyz*

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ABSTRACT

Taraxacum kok-saghyz (TK) is a promising domestic alternative for imported natural rubber. Planting practices like planting density and length of growing season are key parameters influencing crop biomass and rubber yield. We compared seven planting densities; 0.1, 0.2, 0.3, 0.5, 1, 2 and 4 million plants/acre spread over two different trials, one planted in the spring and the other in the autumn. In each trial, half of the plants were harvested after six months and the other half after one year. Harvested plants and roots were weighed, and root rubber concentration determined. Optimal planting density appears to range between 500,000 and 1,000,000 plants/acre. Plants respond differently to season depending upon planting date, plant age and length of the growing season. Overwintering of mature plants leads to a reduction in overall yield per acre. A prime TK selection target is rapid seedling growth, and a more balanced distribution of spring shoot-to-root ratio in autumn planted TK.

INTRODUCTION

Taraxacum kok-saghyz (TK) is a rubber producing plant in the early stages of crop domestication. TK grows in temperate climates and produces high quality natural rubber (NR) very similar to NR produced from *Hevea brasiliensis*, a tropical tree grown primarily in Southeast Asia. World NR shortages of 1.5 megatons (MT) are forecast by 2020 because of increasing demand by developing countries (International Rubber Study Group, 2012). The United States imports 1.2 MT of NR each year. Natural rubber produced from TK would supplement the production of NR from *Hevea*. Ohio can become a leader in TK NR production because of suitable climate, and its established farm and rubber manufacturing infrastructure.

Crop-specific, ideal planting density is key to maximum crop yield in all cultivated species. Therefore, planting density trials were conducted with TK to compare seasonal effects of density on plant and root size, plant survival rate, and rubber concentration and yield.

MATERIALS AND METHODS

Two separate TK planting density trials were completed between May 2013 and November 2014 (Figs.1& 2). Plot set up and experimental design for both trials was identical, excluding plant density. Plots were weeded by hand weekly.

For each trial, TK seedlings were transplanted at four densities, either high (0.5, 1, 2 and 4 million plants/acre) or low (0.1, 0.2, 0.3 and 0.5 million plants/acre) into four outdoor raised planting boxes measuring 4'x6'x2'.

- Each density was duplicated and randomly assigned one half of a box, making 8 total plots.

Six months after transplanting, two quarter sections of each plot were selected randomly and harvested.

- For each harvested quarter plot, plant and root fresh weight of each plant was measured.
- Roots were sorted into five size classes, with 1 assigned for the largest roots and 5 assigned for the smallest (data not shown).
- Roots from the two quarter plots were pooled and 3 representative samples from each size class were taken for Latex Quantification (LQ) and Accelerated Solvent Extraction (ASE) to quantify rubber concentration and rubber yield.

Twelve months after planting, the remaining plots were harvested and evaluated using the above described methods.

RESULTS

Healthy stands were obtained at all densities although the rosettes assumed a vertical orientation with crowding (Fig. 1). Rubber concentration in the high density trial was higher in the one year-old plants, after overwintering, than in the six month-old plants harvested in the autumn (Fig. 2, upper panel). Planting density had little consistent effect on rubber concentration at both harvest times. However, half of the plants at all densities in this trial, died during the winter (data not shown), and overall yield per acre lessened as a result. When plants were established in the autumn and then overwintered (Fig. 2, lower panel), the rubber concentration in the six month old spring-harvest plants was dependent upon planting density, with concentration increasing with density. However, summer growth led to a leveling out of these differences, and, as for the first trial, one year-old plants had a similar root rubber concentration across densities.

Figure 1. Outdoor planting boxes containing TK plants at different densities.

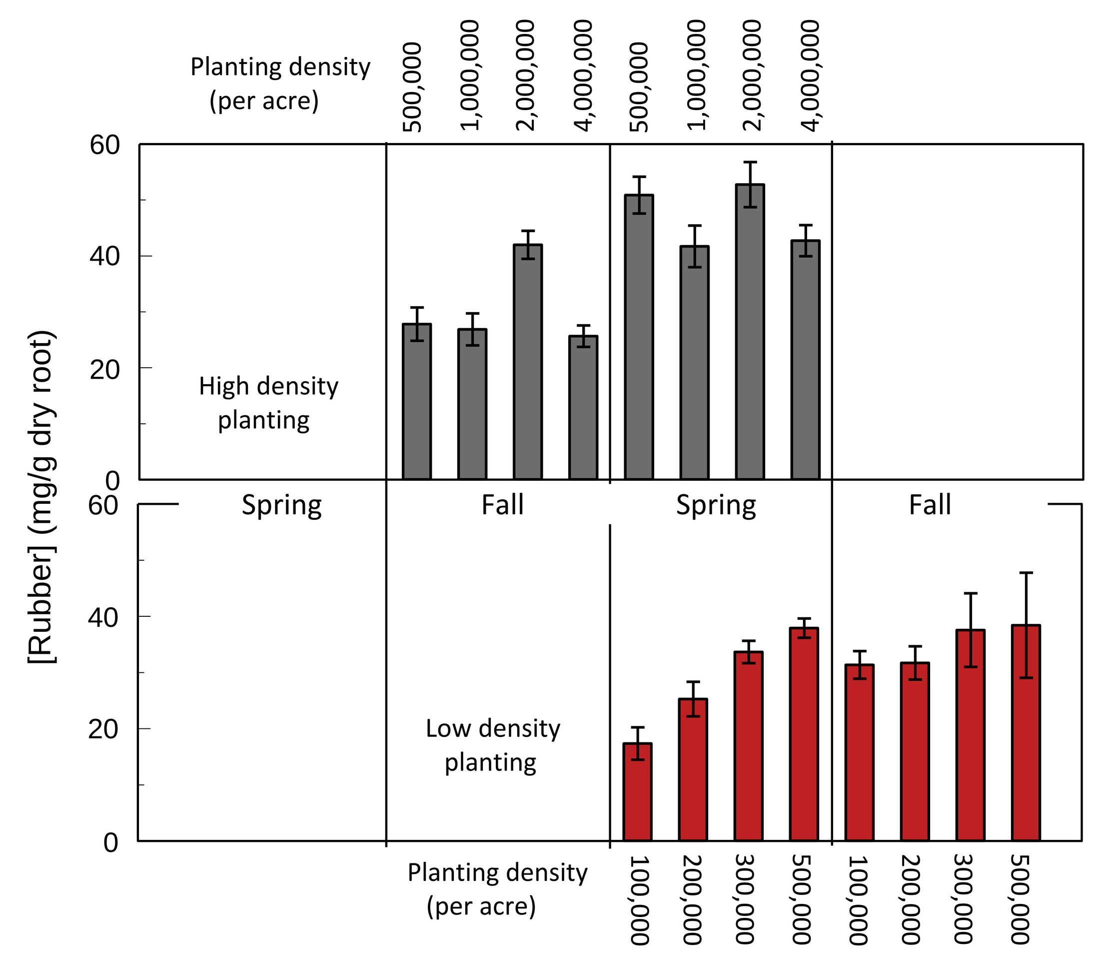

Figure 2. Rubber concentration in TK roots in two trials (upper and lower panels) grown in outdoor planting boxes at different plant densities. Each value is the mean of 15 ± s.e.

Planting density had a major effect on plant size. Higher densities resulted in mostly very small plants (Fig. 3, top panel). Densities of 1 million plants/acre and below all contained plants of a wide size range, and large plants were common. However, planting season and growing season both strongly affected plant architecture and in very different ways. When TK was overwintered as mature plants (Fig. 3, top panel) large plants did not survive the very cold winter of 2013/2104 (low temperatures of -26°C), and overall, one year-old plants and roots were smaller at harvest than the six month-old plants.

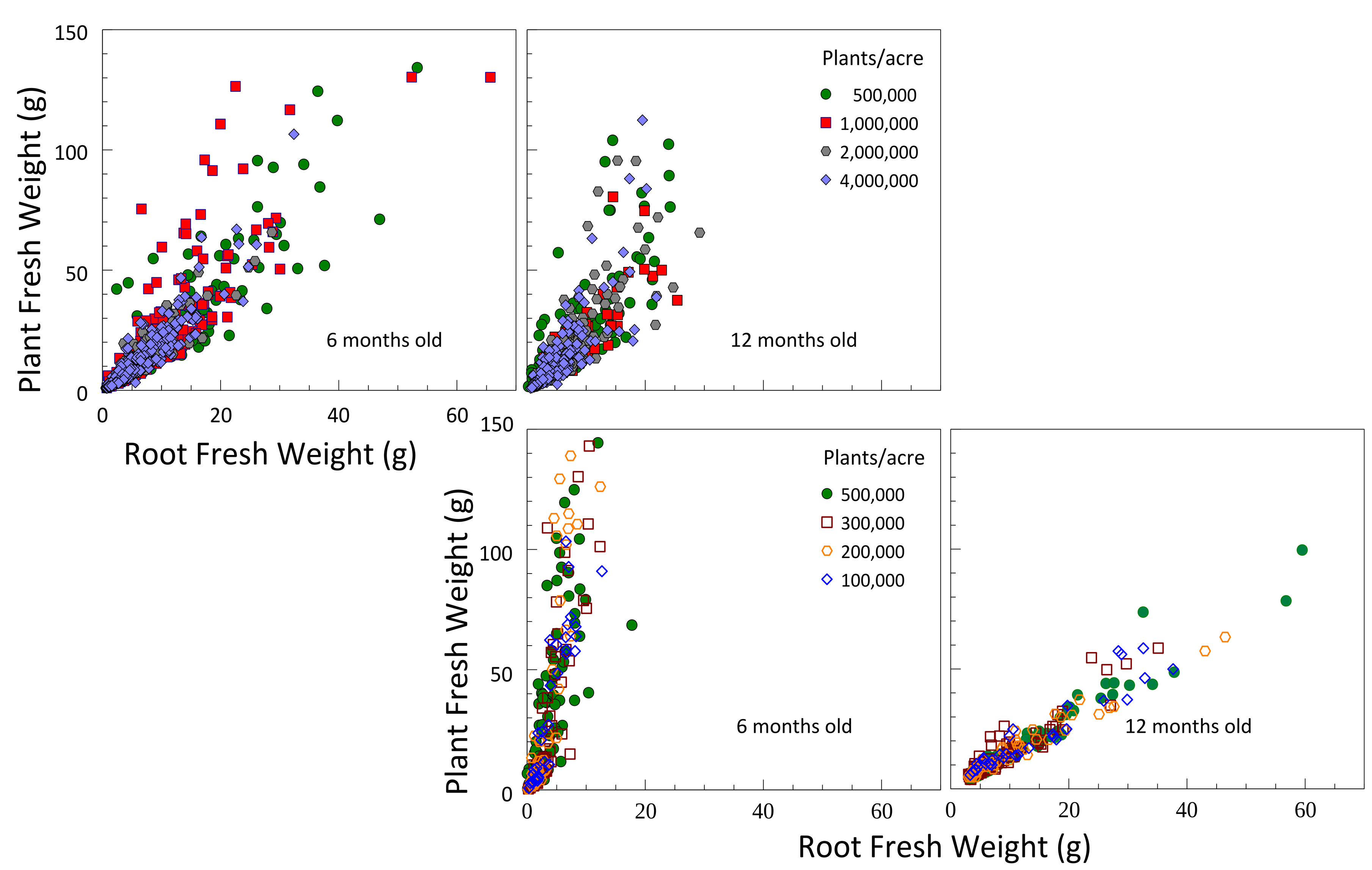

Figure 3. Relationship of plant fresh weight s and root fresh weight as a function of planting density and planting time. These graphs match the timeline shown in Figure 2.

Remarkably, when TK was established in the autumn, and then overwintered, spring growth was almost entirely targeted toward rosette development (Fig. 3, lower left panel), and roots of these plants were much smaller than in plants of the same age planted the previous spring (Fig. 3 upper left panel). During the next six months, these small rooted plants developed large roots, similar to those found in the six month-old plants in the previous trial at autumn harvest time (Fig. 3 cf. upper left panel and lower right panel). Very small plants (<3g) were not apparent at this harvest (Fig. 3 lower right panel). However, overall plant size declined between the spring and autumn harvests, due to loss of rosette biomass (Fig. 3 cf. lower left and right panels).

DISCUSSION

Based on root size and rubber concentration, optimal plant density appears to be between 500,000 and 1,000,000 plants/acre. Higher planting densities caused stunting of the plants due to crowding. Plants at low planting densities did not grow larger than plants at 500,000 plants/acre, suggesting that they were at maximum capacity and could not capitalize on additional space and resources. Large plants tended to die during winter. This is likely due to the tendency of large roots to split and not survive freezing conditions. A plant going into summer with a very small root and a disproportionately large rosette, will die, likely due to an inability to draw sufficient water from the roots for adequate transpirational cooling. Proportional, and larger plants, tend to lose some or all of their leaves during summer, while the roots survive. As the weather cools, new leaves are grown but do not attain the rosette size produced during spring growth.

These results will help guide decisions of when TK should be direct seeded and harvested in the field. The results suggest that a spring transplant and a harvest six months later will maximize rubber yield, and this can be coupled with cold storage post harvest (Cornish et al., 2013). However, transplants are too expensive for commercial TK acreage, and direct seeding is required. Seeding in the spring results in plants that grow very slowly for the first two months, and these plants may not get a sufficiently long growing season to develop large roots with high rubber content. An autumn planting would make sense if it can give the plants a head start over a spring seeded crop, because a longer growing season might be achieved. However, plant loss is likely during this first winter. In both scenarios, overwintering of mature rubber production plants is counterproductive, although overwintering is necessary for TK seed crops.

CONCLUSIONS

A planting density between 500,000 and 1,000,000 plants per acre is optimal for rubber yield. Our results indicate that a prime TK selection target is rapid seedling growth, and a more balanced distribution of spring shoot-to-root ratio in autumn planted TK. This plant type could allow an autumn or spring direct seeded planting of a production TK crop followed by an autumn harvest. Planting techniques and germplasm advances will continue to accelerate the transition of TK from an experimental rubber source to an established, and major, domestic rubber crop.

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