European Journal of Agronomy 93 (2018) 126–134

Contents lists available at ScienceDirect

European Journal of Agronomy

journal homepage: www.elsevier.com/locate/eja

Yield performance of Russian dandelion transplants (*Taraxacum koksaghyz* L. Rodin) in flat bed and ridge cultivation with different planting densities

Marie Eggert*, Joachim Schiemann, Katja Thiele

Julius Kühn-Institute, Federal Research Centre for Cultivated Plants, Institute for Biosafety in Plant Biotechnology, Erwin-Baur-Str. 27, 06484 Quedlinburg, Germany

ARTICLE INFO

Keywords:
Renewable raw materials
Biomass increase
Natural rubber
Dandelion roots
Inulin
Raised bed

ABSTRACT

As shown for other valuable crops, transplanting of wild rubber-producing *Taraxacum koksaghyz* (Tks) could be an option to counteract poor field emergence and stand establishment after direct seeding. Field trials (spring planting, autumn harvest) were conducted in 2012 and 2013 on a loamy soil (Quedlinburg, Saxony-Anhalt, Central Germany) to investigate the influence of different planting beds (flat, ridge) and planting densities (222,222 plants/ha, 88,889/133,333 plants/ha) on the yield performance of Tks. Between planting date and harvest significant plant losses of 43–48% occurred across all treatments in both trial years. Major plant losses occurred within the first month after transplanting. The achieved planting density (APD) at harvest was significantly influenced by year, targeted planting density (TPD) and type of planting bed. Nearly all yield parameters were significantly influenced by the year of cultivation. There was a significant advantage of ridge over flat bed cultivation regarding achieved planting density, fresh root yield per hectare, and fresh/dry root yield per plant in the season 2013 and within the reduced planting density. In ridge cultivation root yield parameters were increased by 5–13%. Furthermore planting density had a significant effect on biomass yield. There were weak to strong positive linear correlations ($r = -0.35$ to 0.75) between achieved planting density and biomass per hectare (fresh/dry root/leaf) and moderate negative correlations ($r = -0.49$ to 0.57) with individual plant yield (fresh/dry root/leaf, rubber/inulin). The presented study demonstrates that transplanting of Tks on ridges can be an option to increase root yield of Tks and that the focus of future research activities should be laid on an optimization of Tks transplant production and management in the field.

1. Introduction

Russian dandelion (*Taraxacum koksaghyz* L. Rodin, Tks), also named Kazakh dandelion or Buckeye Gold, belongs to the worldwide spread genus of *Taraxacum* and is considered as a promising candidate for the domestic rubber and inulin production in many countries worldwide e.g. Russia, Canada, United States and Germany (Krotkov, 1945; Whaley and Bowen, 1947; Ulmann, 1951; Van Beilen and Poirier, 2007a).

Natural rubber (NR) is a biopolymer that consists of hundreds to ten thousands of isoprene units (C_5H_8) linked in 1,4 *cis*-configuration, occurring in many different plant species (Schulze Gronover et al., 2011). The average molecular weight (mw) of the poly-*cis*-isoprene of NR from the rubber tree, *Hevea brasiliensis*, is about 1300 kD (Van Beilen and Poirier, 2007b). The mw of poly-*cis*-isoprene isolated from Tks roots is in a similar range or even higher (Van Beilen and Poirier, 2007b; Kreuzberger et al., 2016). The rubber amount of Tks ranges between 3 and 28% of the dry root mass depending on plant material and growing conditions (Lipshitz, 1934). The Tks material available to the authors (progeny of the USDA Tks germplasm collection) showed a rubber concentration of 3–9% in the dry root depending on the developmental stage of plants (Kreuzberger et al., 2016). NR is a strategic material. 154,000 tons of NR originating from the *Hevea* tree were used for tire production and In 2015, 64,000 tons of NR were processed as latex (medical devices, hygiene products, baby articles) in Germany (Wdk, 2015). Despite the high quality attributes of NR gained from other rubber-producing plants such as Tks or Guayule (*Parthenium argentatum)*, to date *Hevea* NR remains the sole economically important source (Van Beilen and Poirier, 2007b).

Aside from polyisoprenes, 25–40% of the dry root is composed of inulin (Ulmann, 1951; Whaley and Bowen, 1947) which is a polydisperse fructan linked in 2,1 *beta*-configuration used in food industry for several applications such as sweetening or improving texture (Mensink et al., 2015). Commercially available inulin is mostly obtained from *Cichorium intybus* and exhibits an average polymerization degree of 10–20 (Flamm et al., 2001). The polymerization degree of Tks

---

* Corresponding author.
E-mail address: marie.eggert@julius-kuehn.de (M. Eggert).

https://doi.org/10.1016/j.eja.2017.12.003
Received 16 February 2017; Received in revised form 27 July 2017; Accepted 15 December 2017

inulin ranges from 8 up to 30 depending on growth stage/harvest time of the plants and the inulin quality is therefore comparable to that from commonly available plant sources (Kreuzberger et al., 2016). However, recent studies on the agronomic performance of Tks have shown that biomass, rubber and inulin yields are low and currently not competitive with established commercial sources like *Hevea* (rubber) and *Cichorium* (inulin) (Arias et al., 2016a; Kreuzberger et al., 2016; Arias et al., 2016b).

Publicly funded research activities in academic institutions and industry in Europe (EU-PEARLS – Grant Agreement (GA) No. 212872, DRIVE4EU- GA No. 613697) and Germany (TARULIN GA No. 0315971, TAKOWIND GA No. 22002312; EVITA GA No. 031A285A) aim at turning Tks from a wild plant into a new commercial crop with the general objective to support the local production of renewable raw materials (e.g. rubber, inulin, latex). The field study described here was part of a research collaboration (TARULIN) covering diverse aspects of Tks breeding, agronomy, processing and product development. The agronomic research activities of the project aimed at the cultivation of Tks under various field conditions and the documentation of its yield performance under the influence of different agronomic measures. The temporal yield performance of a Tks stand established by sowing was described by Kreuzberger et al. (2016). The establishment of Tks stands via direct seeding has been the most common approach in the former Soviet Union and the United States (Whaley and Bowen, 1947). However, also transplanting (planting seedlings) is conceivable for large scale Tks cultivation even though the former is obviously the less labor (Suomela, 1950) and cost-intensive approach. However, to date plant establishment and subsequently yield performance of Tks via direct seeding faces several obstacles (e.g. low field emergence, slow juvenile plant development, overlapping growth stages) that need to be overcome to gain a dense crop and stable yield. The study of Kreuzberger et al. (2016) emphasized the need for improving the seeding technique and the need for the development of seeds with high seed vigor. These drawbacks might partially be overcome by establishing Tks in the field with transplants. The production of Tks transplants includes the production of Tks seedlings under controlled environmental conditions (e.g. in the greenhouse) and their transfer to the field. E.g. in sugar beet, transplanted beets showed higher root yield than seeded beets, due to an increased length of the growing season which enhanced an earlier and faster development of the leave canopy and roots of transplants (Theurer and Doney, 1980). This faster growth was associated with an increased photosynthetic activity and hence increased assimilate transport to the roots. In vegetables, reasons for transplanting are earlier harvest, better control of abiotic and biotic stresses in the greenhouse, as well as an optimal stand with clearly defined plant spacing and uniform physiological plant age in the field compared to direct seeding (Schrader, 2000).

This study aimed at 1) establishing Tks in the field by transplanting and 2) exploring the impact of this cultivation regime on the yield performance of the transplants with regard to biomass, rubber, and inulin after one season (spring planting, autumn harvest) with the overarching goal of improving/maximizing Tks yields. The latest documented experiments with Tks stands established with planted seedlings were made in Finland in 1944–46 on small areas with sand soil (Suomela, 1950).

Based on the soil texture at the trial site (heavy loam) and the available harvesting technique (potato harvester) for Tks roots, it was decided to grow Tks in two types of planting beds, flat beds and ridges. Due to reduced soil compaction and subsequently increased harvest depth, a higher amount of root mass was expected to be harvested from the ridges when compared to the flat bed situation. Additionally, seedlings were planted in two planting densities (222,000 plants/ha versus 89,000 plants/ha (2012), 133,000 plants/ha (2013)) in order to investigate a potential impact caused by the competition between plants on the yield performance. Different ridge cultivation systems were already investigated worldwide for different crops (e.g. maize, cotton millet, cowpea, and soybean) with the aim to conserve water (Hulugalle, 1990) or to prevent soil erosion (Liu et al., 2008; Pikul et al., 2001). In Germany the cultivation of potatoes, asparagus and carrots on ridges is common practice. Ridge cultivation of sugar beets resulted in increased beet yield by 5–10% in Northern Germany compared to conventional flat cultivation (Schlinker et al., 2007). In further field trials with sugar beet, white sugar yield was increased by 8.4% compared to flat cultivation (Krause et al., 2009). To the authors' knowledge, there are no suggestions neither regarding planting density for Tks transplants nor their economic production and establishment in the field until today. Hence, this is the first study presenting data on the establishment of Tks via transplanting under field conditions. Targeted planting densities were chosen on the basis of available mechanical equipment at the experimental station.

2. Material and methods

2.1. Study site and crop management

The trials were conducted in two consecutive years (2012, 2013), each trial during one season (spring planting, autumn harvest). The study site was located at the experimental field station of the Federal Research Centre for Cultivated Plants (JKI) in Quedlinburg, Germany. The site (51.4N, 11.8E, 140 m of elevation) is characterized by a temperate climate, influenced by a nearby mountain range (Harz). The long-term mean for air temperature is 8.9 °C and for precipitation 497 mm. The monthly values for temperature and preciptiation during the trial periods are given in Table 1. The soil at the study site was a Chernozem with a loamy texture, a humus content of 2.1% and a pH value of 7.1. Since the soil was well supplied with nutrients (8.2 (P_2O_5), 10 (K_2O), 11 (Mg) mg 100 g soil^{-1}), no fertilizers were applied. The soil mineral nitrogen content (N_{min}) at the time of transplanting was 142 (2012) and 49 (2013) kg N ha^{-1} in the depth of 0–90 cm. Tks was grown at this site for the first time. The previous crop was grass-clover. Weeds were controlled manually.

2.2. Plant material and trial design

The parental population of the Tks seeds used for the field trial in 2012 was gained from 14 Tks accessions (Plant ID W6-35 -156, -159, -160, -164, -166, -168, -169, -170, -172, -173, -176, -178, -181, -182) which were collected by Barbara Hellier in the high valleys of the Tian Shan mountains in Kazakhstan in 2008 (Hellier, 2011) and which were received by the authors from the USDA-ARS National Germplasm System. For seed propagation, seeds of these accessions were germinated under greenhouse conditions and random manual crossings between the accessions were performed. The progeny of these crossings represented a random part of the collected wild individuals which were flowering under these conditions since they were not selected for any other trait. Single Tks seeds had a weight of 0.5 ± 0.06 mg and a germination rate of 77 ± 6%. In 2013, transplants were grown from the seed progeny harvested during the flowering period in 2012. There transplants flowered openly and pollination occurred naturally in the

Table 1
Monthly and average values of air temperature and precipitation for trial period in 2012 and 2013.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Av
Air temperature					°C			
2012	8.8	14.6	15.6	18.1	19.0	14.9	9.6	14.4
2013	8.6	12.6	16.6	20.2	18.8	13.4	11.6	14.5
Precipitation					mm month^{-1}			
2012	26	65	115	90	35	40	2	373
2013	23	53	4	32	30	57	86	285