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Dynamics of long-term adaptive responses in growth and rubber yield among *Hevea brasiliensis* genotypes introduced to a dry sub-humid climate of Eastern India

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A B S T R A C T

The twentieth century has witnessed a transformation of Para rubber (*Hevea brasiliensis*) from a wild tree species to a major plantation crop of South and Southeast Asia. In India, rubber cultivation was started in Southern India because of agro-climatic suitability, but pressure on land resources has necessitated further expansion to neighbouring areas. Earlier attempts to afforest isolated pockets of Central and Eastern India have met with limited success due to various factors. This paper reports a long-term evaluation (sixteen years) of niche adaptation of twelve rubber clones introduced to Eastern India. The growth and survival pattern indicated good adaptability for certain clones such as RRII 430 that recorded the highest girth and tappability. Early yield pattern identified RRII 429, RRII 430, and RRII 422 as higher yielders having 20–30% yield advantage over the control clone RRIM 600. The clones PB 217, RRIM 600, RRIC 100, and RRII 203 showed better stability and moderate yield rankings. There was individual clonal dominance for yield components such as dry rubber content (RRIC 100, RRII 417), bark thickness (RRII 203), and number of latex vessel rows (RRII 430, RRII 417). This is the first report on the performance of the latest Indian rubber clones of the RRII 400 series from the region. The clonal adaptability in this region that can be translated into commercial benefits included rising trend in latex yield and desirable secondary traits. Due to the uncertainty of stress occurrence in the non-traditional regions, planting of genetically variable clones (multiclones) in commercial plantings is important to impart adaptive plasticity. The results assume prominence in the context of expansive rubber cultivation and improving productivity in non-traditional areas and for international multilateral clone exchange aimed at improving global rubber productivity.

1. Introduction

Para rubber (*Hevea brasiliensis* Muell. Arg.), a tree native to Amazonian river basins of South America was a wild species until the late nineteenth century. This was one of the most recently domesticated species of the world to exploit natural rubber from its latex. The milky white latex of Para rubber tree contains more than 30% of *cis*-1, 4-polyisoprene, a natural polymer popularly known as natural rubber. Natural rubber is a vital industrial raw material used for making thousands of indispensable products used by us. Established at the commercial plantation level, global supplies of natural rubber are met mainly from Southeast Asian countries. Thailand, Indonesia, and Vietnam are the major global producers, whereas China, India, and USA are the major consumers of natural rubber (Rubber Board, 2017). As a tropical rainforest tree, Para rubber is adapted naturally to the equatorial climate, and therefore is grown widely under well-distributed rainfall and a temperature range of 25–34 °C (Vijayakumar et al., 2000).

Niche testing is a practice in crop introduction, which is basically testing a new crop at a particular environment. It is in contrast to multi-location testing and looks for site-specific adaptation (Sperling and Ashby, 2000) rather than homeostasis. Since the demand for natural rubber is increasing globally, production and productivity increase is mandated in all rubber growing countries. International Rubber Research and Development Board (IRRDB) is currently encouraging

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multilateral clone exchange programmes between its member nations, wherein widely adapted high yielding clones are mostly preferred for exchange targeting direct adoption for cultivation.

As a novice crop of the twentieth century with great commercial potential, *H. brasiliensis* is largely cultivated in the equatorial belt between 10°S and 10°N latitude, known as the traditional belt. Several crop adaptation trials precede the clonal recommendations for commercial cultivation in these areas. In India, the traditional belt encompasses southern part of Kerala and Kanyakumari district of Tamil Nadu where optimum climatic requirements for rubber cultivation prevails. Being a perennial tree crop, the spread of commercial plantations in traditional regions soon encountered land limitations, which compelled the researchers and policy makers to look beyond the traditional belt for extensive cultivation (Sethuraj et al., 1989). However, the non-traditional regions had limitations, mostly climatic, in the form of extreme weather conditions such as drought, low temperature, and wind for which rubber trees are highly vulnerable. To leverage cultivation in these regions, therefore, requires intrinsic tolerance against biotic and abiotic stresses and adaptation (Priyadarshan, 2003).

India is agro-climatically diverse, and four regions are recognised as non-traditional areas for rubber cultivation. They are Eastern, Northeast, Konkan, and subtropical high-altitude regions (Vijayakumar et al., 2000). In Eastern India, areas that may be marginally suitable for cultivation comprise of selected localities in the states of Odisha (Baripada in Mayurbhanj District, Balasore, and Dhenkanal districts), Chhattisgarh (Sukma in Bastar District), Andhra Pradesh (Rampachodavaram in East Godavari District), and West Bengal (parts of Jalpaiguri District). Some of these areas suffer from severe drought during summer except Jalpaiguri where winter is cooler. Other regions also have climatic limitations such as severe drought coupled with high temperature, low relative humidity, and high light intensity in the Konkan (Chandrashekar et al., 1998); cold, wind, and hailstorms in the Northeast (Priyadarshan, 2003), and cold, landslides, and acidic soils in the sub-tropical high altitude regions.

Successive exploratory surveys in Eastern India (Rubber Board, 1985) have revealed vast potential of these regions not only for extending rubber cultivation but also for integrated rural/tribal area development (Brahmam, 2002; Brahmam and Thirunavoukkarasu, 2005). Consequently, the Rubber Board of India has established a regional research station at Kadlipal in Dhenkanal district of Odisha to evaluate the adaptive and yielding potential of different rubber clones through niche testing trials as well as to develop suitable agro-technologies for the region. Preliminary reports on the performance of a few older *Hevea* clones (Gupta et al., 2001, 2002; Krishan 2013a,b) indicate that the most popular indigenous hybrid clone of the traditional region, RRII 105 does not perform well in this region. Further, no detailed study of clonal adaptation and pattern of genotype × environment interactions in the region is available as of now. Recent reports indicate that five new hybrid clones, RRII 414, RRII 417, RRII 422, RRII 429, and RRII 430 had out-performed RRII 105 in the traditional areas (Licy et al., 2003; Mydin et al., 2011). They were also reported to excel in the non-traditional areas of Northeast India and Sub-Himalayan West Bengal (Antony et al., 2010; Meenakumari et al., 2011; Das et al., 2015). A large-scale clonal evaluation trial of 12 promising clones including the new clones was planted in Bhubaneswar in the state of Odisha during 1996. The objective of this study was to evaluate the clones for their long-term performance in terms of growth, early yield, and desirable secondary traits as a measure of their site-specific adaptation to the local climate. It was hypothesised that clones combining stable high latex yield and growth would possess stress adaptation under the prevailing agro-climatic conditions in the region.

2. Materials and methods

2.1. Experimental location and weather

The trial was planted in the experimental farm of the CSIR-Institute of Minerals and Materials Technology (CSIR-IMMT), Bhubaneswar (20°15′N, 85°52′E and 45 m MSL). The soil type was Inceptisol (Aeric Tropaquept), characterised by sandy loam texture (83.2% sand, 6.6% silt, and 10.2% clay) with pH of 5.52 and EC of 0.076 $dS\,m^{-1}$ (Mohapatra and Panda, 2010). The soil was sufficiently deep for rubber culture. Long-term (50 years) average weather data at the site shows annual average temperature in the range of 22 °C to 32 °C, with a mean minimum of 15.2 °C during December-January and a mean maximum of 37.2 °C during May. Annual average rainfall of 1554 mm is received between June and September through south-west monsoon in 58 rainy days. The highest average monthly rainfall of 367 mm occurs in August (www.weatherbase.com). The region has no serious threat of persistent winds and other adverse factors such as frost, but seasonal cyclonic disturbances are a regular feature.

2.2. Clonal material

Twelve clones including nine indigenous hybrid clones, a primary clone, and three exotic hybrids were included in the trial (Table 1). Among these, RRIM 600 was widely acclaimed as a clone adapted to non-traditional areas. Developed from the cross between Tjir 1 and PB 86 in Malaysia, RRIM 600 is a clone that was tested and cultivated globally. Its well-known characteristics such as average tolerance to cold and drought, and above average tolerance for wind, qualify itself as an ideal control clone for adaptive comparison. All the clonal materials were maintained in bud-wood (source bush) nurseries, directly cloned from the respective mother trees, before being developed as planting materials for the study.

2.3. Field layout and upkeep

The trial was laid out during 1996 in a randomised complete block design with three replications. Each clonal plot consisted of 25 trees planted at a spacing of 4.9 m × 4.9 m. All the cultural operations and irrigation during the early phase of establishment were given as per the recommended practice for non-traditional areas (Vijayakumar et al., 1998). Three years after planting, on October 29, 1999, a category 5 tropical super cyclonic storm (BOB 03), lashed coastal Odisha with winds gusting to 260 $km\,h^{-1}$ (Thomalla and Schmuck, 2004) and inflicted heavy damage to the young plants. Timely intervention could salvage the trial almost in its entirety by propping up of plants and supply of casualties.

Table 1
Clones included in the study along with parentage.

Clone	Parentage	Origin
PB 217	PB 5-51/PB 6-9	Malaysia
RRIC 100	RRIC 52/PB 83	Sri Lanka
RRII 51	Primary clone	India
RRII 105	Tjir 1/Gl 1	India
RRII 176	Mil 3-2/PB 5-60	India
RRII 203	PB 86/Mil 3-2	India
RRII 414	RRII 105/RRIC 100	India
RRII 417	RRII 105/RRIC 100	India
RRII 422	RRII 105/RRIC 100	India
RRII 429	RRII 105/RRIC 100	India
RRII 430	RRII 105/RRIC 100	India
RRIM 600	Tjir 1/PB 86	Malaysia

PB, Prang Besar; RRIC, Rubber Research Institute of Ceylon; RRII, Rubber Research Institute of India; RRIM, Rubber Research Institute of Malaysia; Tjir, Tjirandji; Gl, Glenshiel; Mil, Milakande.