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Prospects of castor (*Ricinus communis* L.) genotypes for biodiesel production in India

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ABSTRACT

The search for suitable non-edible oilseed crops for production of biodiesel has led to exploration of the potential of castor, hitherto an export oriented commercial oilseed crop in India. In this context, a study was conducted to identify high yielding castor genotypes ideal for biodiesel production. The material evaluated included seed of 15 castor genotypes grown in rainfed conditions of Alfisols at Hyderabad, India. Variability for palmitic, stearic, oleic, linoleic fatty acids was recorded. Ricinoleic acid, the predominant mono unsaturated fatty acid varied among castor genotypes from 86.7 to 92.1%. Correlation coeffecients between fatty acid profile and biodiesel traits were computed. Genotypes 48-1 and DCH-200 exhibited high O/L ratio, low Iodine value (IV) and high cetane number (CN) which indicates higher stability, longer shelf life, quick ignition and greater combustion quality. Genotype DPC-9 exhibited potential as a female parent for development of biodiesel suitable hybrid.

1. Introduction

Biodiesel, an alternative diesel fuel from vegetable oils and animal fats is biodegradable, non-toxic with low emission profiles thus proven to be an environmentally friendly fuel compared to petroleum diesel [1]. Demand for biodiesel has increased due to rise in the petroleum prices during the last few years. Support policies by governments in different countries like Europe, Brazil, Namibia and India gave a fillip to the use of biodiesel fuels for transport like the EU Directive 2003/30/EC in Europe [2]. The National Mission on Biofuels in India targeted to achieve 20% blending of biodiesel (B20) by 2012 [3]. The mission aimed at bringing 400,000 ha of marginal land under cultivation of non-edible oilseed crops mainly Jatropha. However, castor is a viable alternative to Jatropha due to its shorter growing period and availability of standard agronomic practices for assuring good yields. Jatropha is still a partially undomesticated crop with high yielding varieties in the process of being bred. The availability of improved varieties and hybrids in castor with a yield potential of 1500–1800 kg/ha in rainfed conditions and early maturity within 150–210 days after sowing [4–7] accentuates the need to explore the potential of castor as a biodiesel crop using pure castor methyl esters (B100) or its blend with petrodiesel in different volume ratios (B10 or B20).

Suitability of fatty acid methyl esters (FAMEs) of seed oils as fuel in diesel engines has been documented in the case of many plant species [8,9]. Recent reports on technical feasibility of castor oil as a source of biodiesel indicate that it is a promising alternative source and has many advantages [10,11]. The presence of about 90% ricinoleic acid in castor oil results in its solubility in alcohol at 30 °C. High ricinoleic acid facilitates transesterification without heating and lowers the cost of production. Castor oil in its straight vegetable oil form is about 100 times as viscous as diesel fuel, and transesterification significantly reduces the viscosity. Oil content in castor seed varies from 47 to 49% [12] which is much higher than the values reported for Jatropha [13–15]. This is an

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excellent option for biodiesel production in India since sufficient castor seed to the tune of 850 thousand tonnes is available in the country [16]. The major misconception about the commercial cultivation of castor is the presence of a lethal protein ricin in the endosperm of mature castor seeds. The presence of ricin in its purest form in the castor meal or cake after the extraction of castor oil reduces the value of protein rich castor meal as an animal feed.

Castor is a cross-pollinated crop and till date 14 hybrids and 18 varieties have been released in India [5,6]. The information on suitability of castor genotypes for biodiesel production and correlation with quality aspects has not been generated until now and is highly essential for breeding and selection of efficient biodiesel yielders. With this objective, 15 castor genotypes were evaluated for their fatty acid profile and the biodiesel related traits like saponification number, iodine value and cetane number.

2. Materials and methods

Fifteen castor genotypes comprising of 5 hybrids along with their parental lines and two varietal checks were raised on Alfisols under rainfed conditions at Hyderabad, India (Table 1). Each entry was sown in four row plots of 10 plants per row with a spacing of 90 cm between rows and 65 cm between plants in the month of July. Standard agronomic practices were followed for raising the crop. The crop was harvested at physiological maturity when capsules turned yellowish brown. Seed yield (g) was recorded from net plot (10.8 m^2) in three pickings and cumulative seed yield (kg/ha) was computed at final harvest, when the crop was 150 days old.

Heterosis for biodiesel traits was calculated as the increase or decrease of the hybrids over the parental mean with the following formula and expressed in percentage [17].

$$\text{Heterosis}(\%) = (\bar{x}F_1 - \bar{x}MP)/\bar{x}MP \quad (1)$$

where $\bar{x}F_1$ is the mean performance of the F_1 hybrid; and $\bar{x}MP$ is the average performance of the two parents (female and male lines).

Standard heterosis is the proportion of deviation of value of the test entry from the value of check variety.

$$\text{Standard heterosis} = (\bar{x}F_1 - \bar{x}SC) \times 100/\bar{x}SC \quad (2)$$

where $\bar{x}F_1$ is the mean performance of the F_1 hybrid and $\bar{x}SC$ is the mean of standard check.

In the present study, among the two check varieities, Co-1 is a perennial variety while PCS-4 is an annual variety with early duration (110–150 days maturity) [5,6]. Standard heterosis is calculated over both the check varieties, as genotypes suitable for biofuel purpose may be cultivated both as perennial and annual type.

Seed oil content of castor genotypes was estimated with Nuclear Magnetic Resonance technique [18] and oil yield was computed. To determine fatty acid composition, castor oil was extracted into methanol and intensified using sodium methoxide. Fatty acid profile of the oil was determined by gas chromatography. A Thermo Focus GC filled with a DB225 polar column (30 m, 0.322 mm, 0.25 μ) and FID was used for the analysis of fatty acid composition. The temperatures of oven, injectors and detector blocks were maintained at 210, 230 and 250 °C, respectively. [19].

Fatty acid peaks were identified by comparison with relative retention times of the standard fatty acid methyl esters (FAMEs). Concentration of each fatty acid was recorded by normalization peak areas using GC post-run analysis software, manual integration and reported as percent of the particular fatty acid. Saponification number (SN) and iodine value (IV) of oils were calculated from obtained fatty acid methyl ester compositions of oil with the help of Eqs. (3) and (4), respectively [20]

$$SN = \sum (560 \times A_i)/MW_i \quad \text{expressed as mg KOH/g oil} \quad (3)$$

$$IV = \sum (254 \times D \times A_i)/MW_i \quad \text{expressed as } I_2/100\text{ g oil} \quad (4)$$

Table 1 – Castor genotypes evaluated for fatty acid profile and biodiesel traits.

Genotypes	Pedigree	Areas of adaptation /specific characters
Hybrid		
DCH-32	LRES-17/DCS-5	Rainfed regions of Southern India, resistant to leaf hoppers
DCH-177	DPC-9/DCS-9	Rainfed regions of Southern India, resistant to *Fusarium* wilt
GCH-4	VP-1/48-1	Both rainfed and irrigated regions of India, resistant to leaf hoppers
DCH-171	M-619/DCS-9	Suitable for rainfed regions of India, resistant to *Fusarium* wilt
DCH-200	DPC-9/Aruna	Suitable for rainfed regions of India, resistant to white flies
Female lines		
LRES-17	VP-1/HC-8	Dwarf, resistant to leaf hoppers
DPC-9	VP-1/REC 128-1	Resistant to *Fusarium* wilt
VP-1	TSP10R/JI-15	Dwarf, resistant to leaf hoppers
M-619	Mutant VP-1	Resistant to *Fusarium* wilt
Male lines		
DCS-5	240/Bhagya	Early maturity (90–150 days)
DCS-9	240/Bhagya	Rainfed areas of Southern India, resistant to *Fusarium* wilt
48-1	HO/MD	Both rainfed and irrigated regions of India, resistant to *Fusarium* wilt
Aruna	Mutant HC-6	Rainfed areas of Southern India, tolerant to jassids
Checks		
PCS-4	Pb-1/151-b)//(Jc-44/413A)	Rainfed areas of Andhra Pradesh, annual variety, tolerant to drought
Co-1	–	Sub marginal lands of Tamilnadu, perennial variety