



## **Effect of Certain Rootstocks on Vegetative, Reproductive Growth and Yield of Cashew Cultivars**

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### **Authors' contributions**

*This work was carried out in collaboration among all the authors. Author JDA designed the study and all authors conducted the experiment. Author PJ wrote the manuscript with support from authors JDA and DK. All authors read and approved the final manuscript.*

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### **ABSTRACT**

Vigour reduction through dwarf rootstocks is an essential element of high density planting systems. Cashew is a vigorous evergreen perennial woody plant that is traditionally cultivated in a low density planting system. The present investigations were carried out at ICAR-Directorate of Cashew Research, Puttur, Karnataka, India to find out the effects of vigour controlling rootstocks on vegetative growth and yield of cashew cultivars. The experiment was laid out in a randomized block design with twelve combinations of scion/rootstock with three replications. Different growth habits of four cashew varieties scions (Ullal-3, VRI-3, NRCSel-2 and Vengurla-4) grafted on two dwarfing rootstocks (NRC-492 and Taliparamba-1) and one vigorous rootstock (Vengurla-4) were studied. The results revealed that various stionic combinations varied to growth and yield parameters. Significant interactions indicated that Taliparamba-1 (dwarfing rootstock) with VRI-3 consistently reduced the growth and vigour based on their lower mean tree height, plant volume, TCSA and canopy spread. Stionic combination of VRI-3/ NRC 492 recorded the highest cumulative nut yield of

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16.77 kg/ tree (5 seasons of cropping). Based on observation on growth and yield of various stionic combinations revealed that NRC 492 could be used as a rootstock to induce semi dwarfism with a higher nut yield.

**Keywords:** *Anacardium occidentale* L.; rootstock; tree vigor; yield.

## 1. INTRODUCTION

Cashew (*Anacardium occidentale* L.) is an important export-oriented high-value commodity from India that is traditionally cultivated in western and eastern coastal areas of this country. The present production of cashew is 817 (000 MT) from 1062.042 (000 ha) and with a productivity of 753 kg/ha [1]. Cashew production is characterized by extensive plantations of low-density orchards (8m × 8 m or 7.5 m × 7.5 m) orchards (156 to 175 trees ha<sup>-1</sup>) planted as a seedling with poor canopy management and non-adoption of an improved package of practice lead to low net returns of early production and low productivity of cashew [2]. These problems have been reduced by the widespread adoption of the quality planting material, cultivation of improved varieties/hybrids, adequate plant density, canopy management and integrated nutrient management (INM). Recently, the limited availability of cultivable land is as together with the growing global demand for cashew has given a thrust to the concept of high-density planting (HDP).

Cashew is a vigorous evergreen perennial woody plant with long juvenility and high heterozygosity. Canopy development in cashew is a seasonal and continuous process. However, the varieties of cashews currently available are semi vigorous to vigorous. Canopy management has a direct influence on plant vigour which ultimately influences the cashew nuts yield. The manipulation of the canopy by training and pruning, plant growth inhibitors and dwarfing rootstocks is an important management practice to regulate vegetative growth, flowering and yield in fruit trees [3]. The response to pruning depends on age, growth habits, tree vigour, varieties, location and cultivation practices of cashew. Heavy pruning promotes excessive vegetative growth and often reduces the yield due to the dense canopy with reduced flowering [4]. The application of plant growth retardants such as paclobutrazol has been found useful in the manipulation of vegetative growth, vigour and yield of cashews [5,6]. The optimized application of PBZ to obtain maximum benefit with minimum

undesirable impact on food and environmental safety aspects [7].

Using dwarfing rootstocks offers the possibility to manipulate tree vigour, better anchorage, nutrient uptake, tolerance to biotic and abiotic stress, as well as yield and productivity without increasing input costs [8]. Rootstock selection is a critical tool for the management of vegetative and reproductive growth of scion in perennial fruit crops, which are propagated by grafting or budding. Numerous studies have shown that they offer the advantage of rootstocks in the cultivation of tropical and temperate fruit crops on aboveground tree growth and yield [4,8,9]. Very limited studies have been investigated on cashew to select suitable rootstocks to modify scion vigour and increase productivity. Our research is mainly focused on the effects of vigour controlling rootstocks on vegetative growth and yield of cashew cultivars. In this study, preliminary results reported by [10], provided background information for the performance of vigorous cashew cultivars as influenced by dwarf rootstocks (2008-12).

## 2. MATERIALS AND METHODS

### 2.1 Planting Materials and Growth Conditions

The experiment was initiated with a nursery trial in 2007 at Experimental Station of Directorate of Cashew Research (DCR), Santhigodu, Karnataka, India (12.45°N latitude, 75.4°E longitude and 90 m above MSL). The experimental site is laterite has a sandy loam with acidic nature (pH 4.8–5.3) and available nitrogen: 203–247 kg ha<sup>-1</sup>, P<sub>2</sub>O<sub>5</sub>: 7.0 to 7.3 kg and K<sub>2</sub>O: 112 to 198.0 kg of the soil. The study area is located along the West Coast region of India, where the climate is tropical, with distinct dry seasons (from January to May) and 3500 mm of average annual rainfall and is distributed from late May to November. The daily records of maximum and minimum temperatures and Rainfall for the period April to March of the years

2013 to 2016 was obtained from meteorological observatory, ICAR-DCR, Puttur.

The four high yielding varieties of cashew, Vengurla-4 (vigorous, compact canopy) Ullal-3 (vigorous with open canopy), NRCSel-2 (medium vigorous, medium compact canopy) and VRI-3 (medium vigorous, compact canopy) scions grafted on the three rootstocks NRC 492 (Brazil dwarf) Taliparamba-1 and Vengurla-4. Vengurla-4 is a hybrid (Midnapore Red x Vetore 56) and vigorous variety served as a rootstock check. For rootstock propagation, seeds (NRC 492, Taliparamba-1 and Vengurla -4) were collected from the experimental farm, ICAR- DCR, Santhigodu and planted in nursery polybags (25 cm x 15 cm) containing a 1:1:1 of soil, sand and FYM. The seedlings were placed under 50% shaded nursery with *regular* watering. After two months, the seedlings were grafted (softwood) with scion varieties like Ullal-3, VRI-3, NRCSel-2 and Vengurla-4 (V-4). In 2008, successful one-year-old grafts were planted at 6m x 6m spacing. There were 12 treatments arranged in a randomized complete block design (RBD) with three replications and six plants per replication. After planting, all the trees were maintained under regular intercultural operations as recommended.

## 2.2 Measurements of Growth and Yield Parameters

Three years after planting, the grafted trees were evaluated from 2011-12 (data published) until 2015-16 in terms of growth and yield parameters. Growth parameters such as plant height, trunk diameter (above and below union) and canopy spread were measured in four plants per replication. Twenty shoots per tree were randomly tagged to measure the intermodal length (cm). The observations on the number of flowering laterals and non-flowering laterals per square meter area were counted from four directions of the canopy using a bamboo frame of a one-meter square [11]. Plant volume ( $m^3$ ) was calculated using the following equation: Plant Volume =  $\pi r^2 h$ . Where  $\pi=3.14$   $h$  = plant height and 'r' indicates the average of canopy spread (E-W and N-S directions) [12]. Trunk cross-sectional area (TCSA) was calculated by  $TCSA (cm^2) = Girth^2/4\pi$  [13]. The cashew nuts were collected manually (February to May) from the ground surface and separated from cashew apple and weighed after drying in the sun for 2-3 days and yield of cashew nut per tree was determined.

## 2.3 Statistical Analysis

The experiment was performed with a randomized complete block design (RBD) with twelve combinations of scion/rootstock with three replications. Data generated from the experimental plot were analyzed by using by AGRES software package. Data on growth and yield attributes were subjected to analysis of variance and the means were compared by the Tukey test at a significance level of 0.05 ( $P<0.05$ ) to determine the significance of differences among the stionic combinations [14].

## 3. RESULTS AND DISCUSSION

### 3.1 Climatic Parameters

The average monthly rainfall and the maximum and minimum temperatures for the period from April to March of the years 2013-2016 are presented in Fig. 1a and Fig. 1b. The total annual rainfall during the 2013-2014 year was 3574.9 mm, 4509.8mm in 2014-15 and 2829.4 mm in 2015-16. The highest *rainfall* distributions were recorded in 1473.8 mm in June 2013, 1374.6 mm in September, 2014 and 998.6 mm in June 2015. *Absence of rainfall* distribution during the months of December, January, February, March during the years 2013-14 and 2015-16 years. The comparison of average maximum and minimum temperatures (Fig. 1b) showed that relatively higher temperatures occurred during 2014-2015 cropping season. The maximum temperature 42.8°C was recorded in October 2014 and minimum 10.1°C temperature was recorded in December 2014.

### 3.2 Annual Tree Growth and Dimensions

Rootstocks could manifest an effect on growth parameters that started when the trees were young and proceed throughout the experimental field. After eight years, plant height, plant volume, TCSA, flowering and yield of different varieties as influenced by rootstocks are presented in Tables 1 and 2. The average plant height on the rootstocks was approximately similar 5 m; and a significant reduction was found in Taliparamba-1 rootstock, which showed a dwarfing effect in the varieties in contrast to the other rootstocks. *There was no difference among the treatments* for tree height (2013-14). The shorter tree height were associated with VRI-3/Thaliparamba-1, VRI-3/ Vengurla-4, NRC Sel-2/ Thaliparamba-1, NRC Sel-2/ Vengurla-4, VRI-3/ NRC492 and Vengurla-4/ Thaliparamba-1 and

the tallest trees were seen in Ullal-3/NRC-492 followed by Ullal-3/Thaliparamba-1 and Vengurla-4/ Vengurla-4 during 2015–2016 and 2016–2017 respectively. The present study clearly indicated that vigour reduction by dwarf

rootstocks of cashew is dependent on stionic combination. In both mango and kiwi, the rate of vegetative growth was more dependent on scion genotype than rootstocks (Willis and Marler [15], Clearwater et al. [16]).

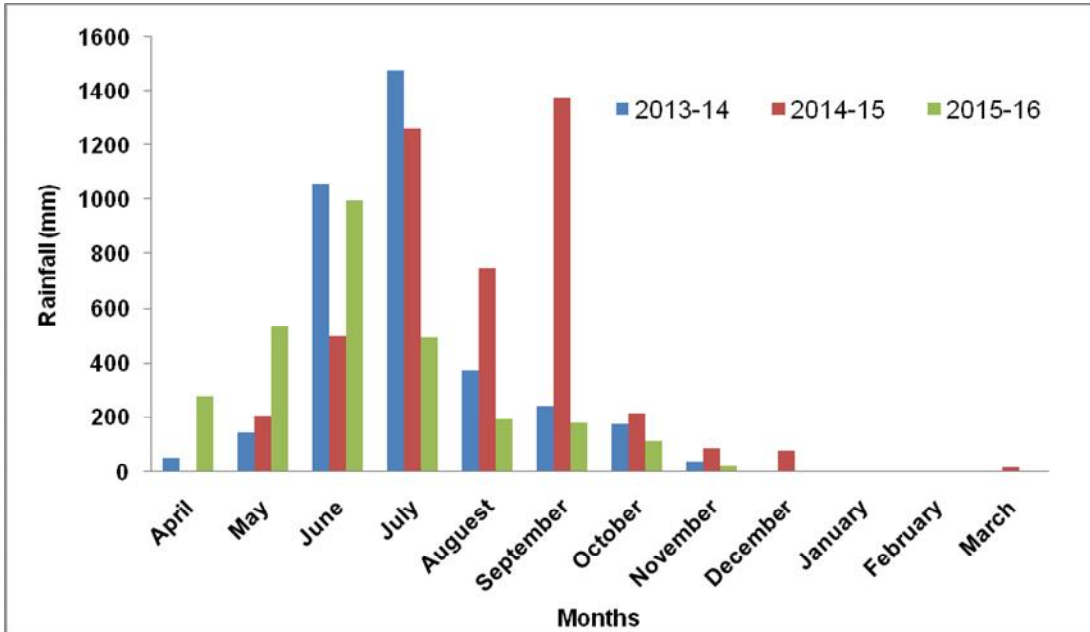


Fig. 1(a). Month wise rainfall data from 2013 to 2016

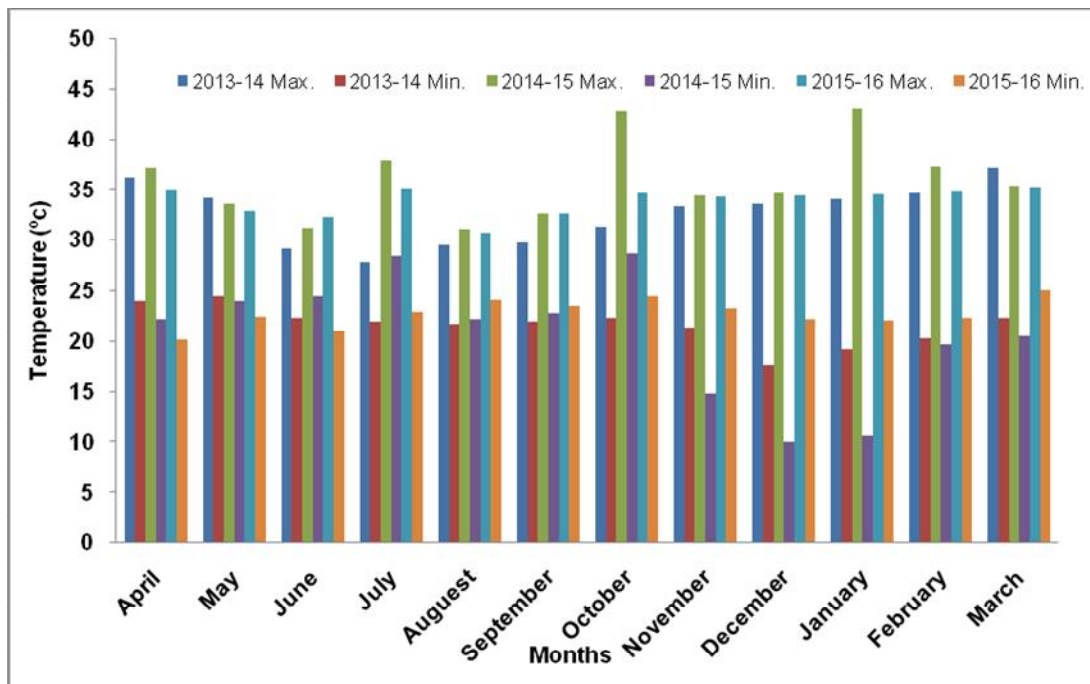


Fig. 1(b). Month wise maximum and minimum temperature (°C) from 2013 to 2016

**Table 1. Effect of rootstocks on plant height, trunk growth rate, rootstock: scion girth ratio and intermodal length of cashew**

Stionic combination (scion/roostock)	Plant height(m)			Girth below union (cm)			Girth above union (cm)			Stock:scion ratio			Intermodal length (cm)		
	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16
Ulla-3/ V-4*	3.61	4.70	5.94	41.34	49.80	55.06	35.06	42.10	49.75	1.18	1.18	1.12	1.21	1.87	0.91
VRI-3/V-4	3.68	4.07	4.63	40.29	46.40	50.33	36.74	40.20	46.44	1.09	1.15	1.09	0.81	1.68	0.82
NRC Sel-2/V-4	3.58	4.31	4.99	38.91	48.60	49.88	35.41	42.40	46.25	1.09	1.14	1.08	0.90	1.92	1.02
V-4/V-4	3.91	5.16	6.42	50.26	56.20	60.47	42.56	49.10	56.07	1.18	1.14	1.08	1.11	1.89	1.16
Ulla-3/ NRC492	4.13	5.63	7.15	52.85	58.20	68.28	44.76	48.90	62.62	1.18	1.19	1.09	0.96	1.89	1.14
VRI-3/ NRC492	3.82	4.16	5.07	49.20	55.70	59.14	41.93	46.70	52.93	1.17	1.19	1.12	0.84	1.70	1.16
NRC Sel-2/ NRC 492	3.88	4.96	5.80	45.70	51.70	57.66	40.74	46.10	53.84	1.12	1.12	1.07	1.12	1.93	1.16
V-4/ NRC 492	3.80	4.76	5.74	44.58	52.60	54.53	37.94	43.80	49.14	1.18	1.20	1.11	1.03	1.90	0.93
Ulla-3/ T-1*	3.91	5.15	6.18	47.50	49.60	56.11	41.08	41.60	52.22	1.16	1.19	1.08	0.89	1.92	1.23
VRI-3/ / T-1	3.26	3.55	4.60	36.52	43.70	50.00	32.10	36.60	45.53	1.14	1.19	1.10	0.88	1.86	1.05
NRC Sel-2/ / T-1	3.66	3.71	4.74	37.08	47.80	49.52	31.91	39.70	41.92	1.16	1.20	1.19	1.04	1.80	0.94
V-4/ / T-1	3.92	4.73	5.34	52.75	52.50	55.88	45.62	45.40	49.88	1.16	1.16	1.13	0.84	1.68	1.21
Grand Mean	3.76	4.57	5.55	44.75	51.07	55.57	38.82	43.55	50.55	1.15	1.17	1.11	0.91	1.82	1.11
SE(d)	0.28	0.38	0.503	5.25	6.48	6.99	4.85	5.84	7.27				0.97	1.84	1.06
CD@5%	NS	0.78	1.04	10.89	NS	NS	NS	NS	NS				0.12	0.06	0.044

Note: \* V-4: Vengurla -4, T-1: Thaliparamba-1 NS: Non-significant

**Table 2. Effect of rootstocks on flowering, non flowering laterals and cumulative yield (kg/tree) of cashew**

Stionic combination (scion/rootstock)	Flowering laterals (m <sup>2</sup> )				Non-Flowering laterals (m <sup>2</sup> )				Cumulative yield kg/tree (5 harvest)
	2013-14	2014-15	2015-16	Mean	2013-14	2014-15	2015-16	Mean	2011-12 to 2015-16
Ullal-3/ V-4*	10.00	11.00	7.50	9.50	8.3	8.30	8.17	8.26	10.46
VRI-3/V-4	12.7	12.90	12.75	12.78	10.0	10.50	5.42	8.64	11.76
NRC Sel-2/V-4	12.7	12.60	9.25	11.52	11.0	11.00	7.00	9.67	11.03
V-4/V-4	12.3	12.40	8.00	10.90	8.7	8.70	6.67	8.02	13.80
Ullal-3/ NRC492	12.3	12.40	8.17	10.96	8.0	8.30	7.92	8.07	14.53
VRI-3/ NRC492	11.3	11.30	10.25	10.95	14.0	14.00	6.42	11.47	16.77
NRC Sel-2/ NRC 492	9.0	9.00	7.17	8.39	12.0	12.00	6.03	10.01	12.50
V-4/ NRC 492	8.3	8.30	9.17	8.59	9.0	9.00	6.17	8.06	13.59
Ullal-3/ T-1	7.5	7.50	7.92	7.64	10.5	10.50	4.00	8.33	13.26
VRI-3/ T-1	11.7	11.70	9.92	11.11	10.0	10.00	6.58	8.86	11.19
NRC Sel-2/ T-1	7.0	7.00	8.75	7.58	9.0	9.00	5.17	7.72	7.84
V-4/ T-1	8.0	8.00	8.38	8.13	11.5	11.50	5.63	9.54	11.74
Grand Mean	10.23	10.34	8.94		10.17	10.23	6.27		
SE(d)	1.48	0.09	0.719		1.73	0.07	0.737		
CD@5%	3.08	0.18	1.491		NS	0.15	1.530		

Note: \* V-4: Vengurla -4, T-1: Thaliparamba-1 NS: Non-significant

The measurement of the *diameter of the above and below graft union* and canopy spread didn't differ significantly. Analysis based on TCSA and plant volume indicated that these parameters varied distinctly among the rootstocks for three years, as shown in Figs. 2 and 3. The small size of 'VRI-3/ Thaliparamba-1' tree was additionally reflected in its low plant volume (141.64 m<sup>3</sup>) in contrast to 'Ullal-3/NRC 492', which produced the largest plant volume of 368.59m<sup>3</sup>. However, both plant volume and TCSA were the largest in 'Ullal-3' trees growing on dwarfing rootstock NRC-492 in all examined years, followed by trees of Vengurla-4 grafted with Vengurla-4. In contrast, VRI-3 trees grafted onto dwarfing rootstock (Thaliparamba-1) produced the least plant volume and TCSA throughout the trial indicated that Thaliparamba-1

has a dwarfing effect in compared with NRC-492 and Vengurla-4. The mean of four varieties grafted on Vengurla-4 rootstock was generally intermediate between Thaliparamba-1 and NRC-492 rootstocks. The TCSA of rootstock is a simple and *useful index* to estimate vegetative growth and fruit yield (Kumar et al. [17] and Dalal and Brar [18]). Kumar et al. [13] reported that trees TCSA had a pronounced effect on the canopy volume, fruit yield and quality of plum. The rootstock/scion ratio used as an indicator for rootstock/scion affinity (Roose et al. [19]). During the three years of this study, the ratio of circumference from the scion to the rootstock revealed that the trunk cross-sectional area of scion was smaller than rootstocks (Table 1). Similar observations were reported in oranges (Legua et al. [20]) and lemons (Perez et al. [21]).

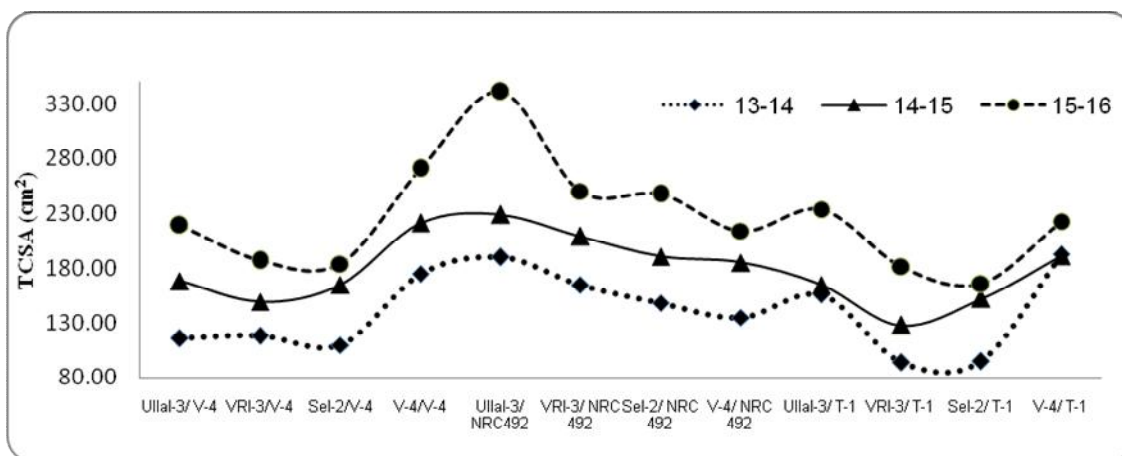


Fig. 2. Trunk cross-sectional area (cm<sup>2</sup>) of different stionic combinations of cashew

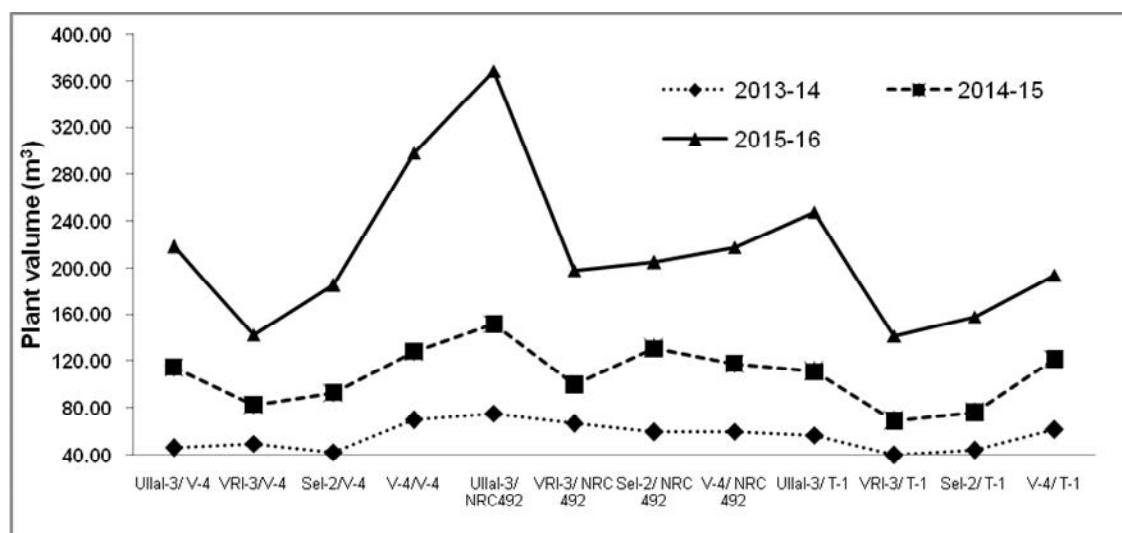
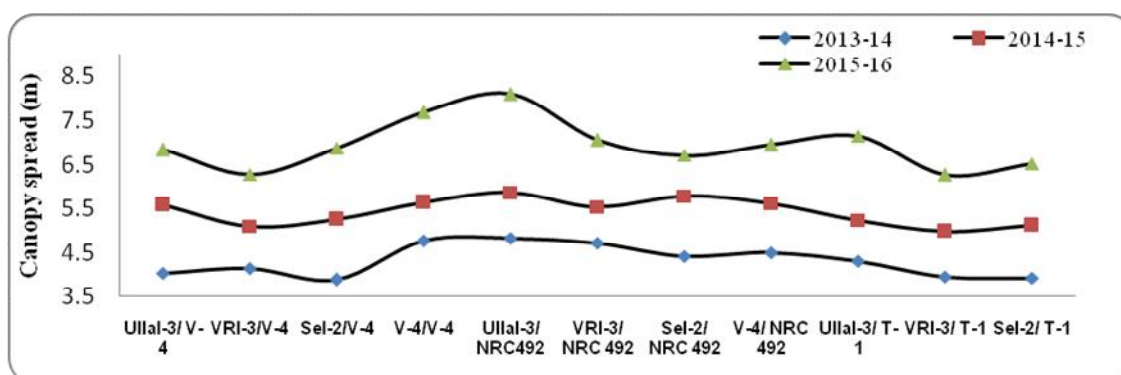


Fig. 3. Plant volume (m<sup>3</sup>) of different stionic combinations of cashew



**Fig. 4. Canopy spread (m) of different stionic combinations of cashew**

During the entire trial, no significant differences in canopy spread were observed among the stionic combinations (Fig. 4). Among the scion cultivars grown on Thaliparamba-1 rootstock, canopy spread was substantially lower in VRI-3 (5.07 m). The stionic combination of Ullal-3/NRC-492 produced the largest canopy (8.10 m<sup>2</sup>), while 'VRI-3/ Thaliparamba-1' produced the smaller canopy (6.26 m<sup>2</sup>). The scion variety Ullal-3 indicated vigorous growth in terms of plant height, canopy spread, plant volume and TCSA irrespective of rootstocks compared to the other three varieties. The results clearly indicated that rootstock effects alter the canopy morphology of cashew varieties. The current research agrees with the finding of Tworowski and Miller [22] in apple.

The different rootstocks significantly affected the internodal length of shoots in all the three-season showing significant variations, but results were not consistent. The dwarfing rootstock Thaliparamba-1 induced lesser internodal length in scion varieties compared with other rootstocks in 2013-14 and 2014-15. The contradictory results were obtained in 2015-16. Comparison of twelve stionic combinations of cashew over the three years revealed that, VRI-3 / Vengurla-4, VRI-3/NRC-492, and Vengurla-4/Thaliparamba-1 recorded the intermediate internodal length (1.10, 1.23 and 1.24). The results of our investigation are in accordance with the results obtained by Somkuwar et al. [23] on growth performance of thompson seedless grafted on different rootstocks.

### 3.3 Yield Parameters

The choice of rootstock can influence the flowering time, floral density, quality and yield (Webster [24]). The number of flowering laterals and non flowering laterals showed a significant

variation among different stionic combinations. The highest flowering laterals per square meter were found in Vengurla-4 rootstocks (11.18). The stionic combinations of VRI-3/Vengurla-4 recorded a maximum number of flowering panicles per square meter (12.75) while the lowest number (7.58) was recorded in the combination of NRCSel-2/ Thaliparamba-1. Also, the combination of NRCSel-2/Thaliparamba-1 (7.72) recorded the lowest number of non-flowering laterals per square meter while and the highest non-flowering laterals was recorded in VRI-3/NRC-492 (11.47) (Table 2). Sethi et al. [25] reported that canopy spread and number of flowering laterals per m<sup>2</sup> are considered predominant traits that contribute to yield of cashew. Costes and Garcia-Villanueva [26] have discovered that the dwarf apple rootstock M9 altered the flowering of two apple cultivars, 'Ariane' and 'X3305'.

The cumulative cashew nut yield in kilograms per tree is presented in Table 2 and cashew nut yield per tree during the different years is depicted in Fig. 5. In general, dwarf rootstock trees produce smaller trees that produce lesser yield per tree than larger trees with the vigorous rootstock. In high-density plantation, accommodation of more number of dwarfed trees compensates for the reduced yield per tree (Webster [24]). In this experiment, the stionic combinations of VRI-3/NRC-492 recorded the highest cumulative nut yield (16.77 kg/tree) followed by Ullal-3/NRC-492 (14.53 kg/tree) and lowest nut yield was recorded in NRCSel-2/ Thaliparamba-1 (7.84 kg/tree). The combination of less vigorous scion/dwarfing rootstock was associated with a higher yield of cashew nut. The results clearly indicate that the cultivar plays an important role in the precocity of particular scion/rootstock combinations. This conclusion is consistent with the findings of Meszaros et al. [27] in pears.



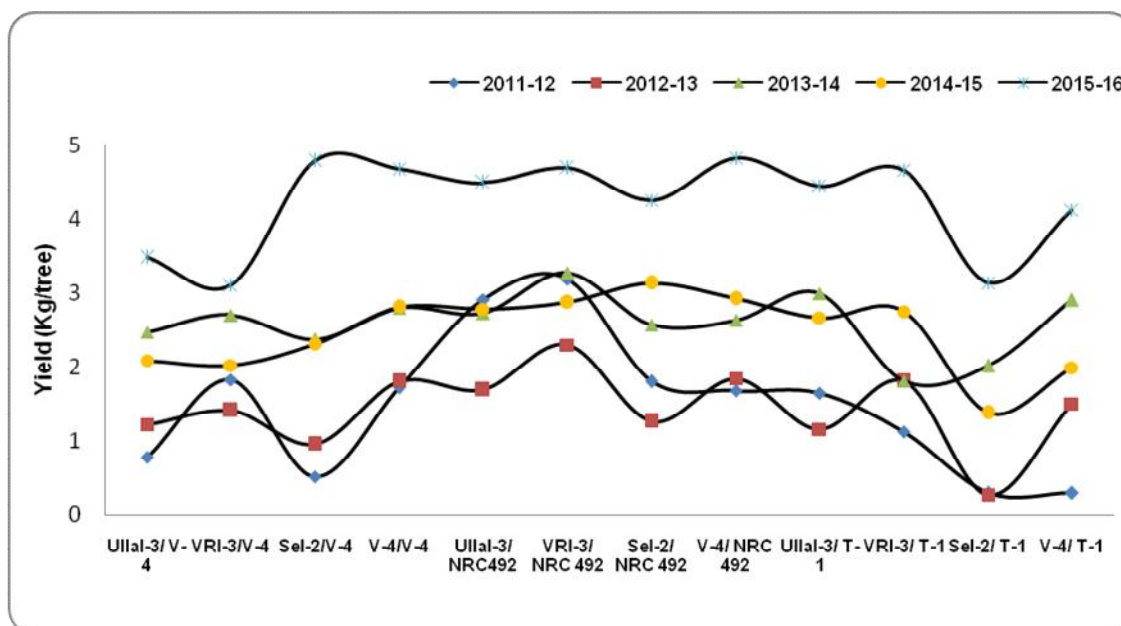


Fig. 5. Cashew nut yield (kg tree<sup>-1</sup>) of different stionic combinations of cashew

#### 4. CONCLUSIONS

This study was conducted to examine the effect of vigorous/ dwarfing rootstocks on growth and yield of cashew varieties scions with various growth patterns. The results showed that different rootstocks differentially influence the morphology of grafted cultivars, including tree height, trunk cross-sectional area (TCSA), internodal length and yield. In present study VRI-3/ Taliparamba-1 had low growth vigour based on low means of tree height, plant volume, TCSA and canopy spread. The stionic combinations of VRI-3/ NRC-492 recorded the highest cumulative nut yield of 16.77 kg/tree (five seasons of cropping). The results demonstrated the possibility of manipulating cashew nut productivity through rootstock. Based on observation on growth and yield of various stionic combinations, it was revealed that NRC-492 could be used as a rootstock to induce semi dwarfism with a higher nut yield. Although cashew is a scion dominant species, the effect of rootstock is reflected in terms of stionic combination in particular, to control the plant vigour of the plant.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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