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Influence of rootstock scion combinations on morpho-physiological traits in Coffee

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Abstract

An experiment was conducted using coffee seedlings to find out the influence of rootstock scion interactions on morpho-physiological traits. Commercially important arabica cultivars such as S.795, Sln.10 and S.4202 were grafted on drought tolerant rootstocks of arabica cultivars such as Sln.9, Sln.5 (B), Sln.11and two high vigour robusta cultivars like S.274 and C x R. Results on morpho-physiological traits indicated significant differences between rootstock scion combinations. The interaction effects in comparison with pure line seedlings of scion materials indicated that, the robusta rootstocks being diploid species (2n=22), significantly reduced the growth of tetraploid (2n=44) arabica scion materials. Results on physiological and morphological traits indicated that the higher vigour in arabica/arabica combinations compared to robusta/arabica and self graft combinations might be due to the influence of genetically divergent rootstocks of same species. Correlation analysis indicated significant positive relationship between specific leaf area and absolute growth rate (r=0.560), net assimilation rate (r=0.498) and relative leaf growth rate (r=0.587) and also leaf area duration with absolute growth rate (r=0.753) indicating role of specific leaf area and leaf area duration in governing growth and development of coffee graft combinations. The Sln.9 and Sln.5B rootstocks for S.4202 scion, Sln.5B and Sln.11 for Sln.10 scion and Sln.9 and Sln.5B rootstocks for S.795 scion were found to be efficient and could be field evaluated for yielding performance.

Keywords: Arabica, diploid, leaf area, physiological traits, robusta, rootstocks

Introduction

Coffee is one of the most important beverage crops belonging to the genus Coffea of the Rubiaceae family. Though coffee cultivation in India is confined to the hilly tracts of Western Ghats with good rainfall, it suffers from drought for a period of 3 to 4 months in a year. Conventional breeding to evolve coffee genotypes with high vigour, drought tolerance, high yielding potential and wider adoptability for abiotic and biotic stresses is a long term process. Grafting in fruit crops has been described as a valuable technique for the improvement of plants having inferior characteristics like poor growth, low productivity etc. (Tubbs, 1973). Many horticultural crops are being cultivated using rootstock scion combinations. Among the several methods, wedge cleft grafting was found suitable for coffee (D'Souza *et al*., 1969; Raghuramulu and Purushotham, 1987; Anilkumar and Srinivasan, 1999). Anil Kumar *et al*. (2003) reported improvement in plant vigour and productivity when arabica scions were grafted to *Coffea excelsa* rootstocks. Grafting of *C. arabica* cultivars on to *C. canephora* or *C. congensis* increased the development of the plants (Fahl *et al*.,1998). Breeding varieties for high vigour in a perennial crop like coffee is a long term process and not much progress has been achieved either in India or else where. Grafting is a tool for imposing desired characters in most of the perennial plants (Raghuramulu, 1994; Anil Kumar *et al*., 2003). Keeping this in view, commercially important scions of three arabica genotypes have been grafted on three drought tolerant arabica (*Coffea arabica* L.) and two important high vigour robusta (*Coffea canephora* Pierre ex. Froehner) rootstocks to find out the influence on growth and development at pre-bearing stage.

Materials and Methods

Experiment was conducted using different rootstock scion combinations during 2008-09 seasons at Central Coffee Research Institute, Coffee Research Station, Karnataka, India (13.22' N latitude, 75.28' E

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longitude and 884 m altitude). The climate during the experimental period was quite normal with a mean max. temp. of 29.6 °C and a mean min. temp. of 18.12 °C, a mean RH of about 85 % and an average rainfall of 2838 mm. The total sunshine hours varied between 4.5 - 8.7 h/ day.

The study was conducted using eighteen months old grafted coffee seedlings raised in polythene nursery bags of 35 cm x 25 cm size, filled with five kg sieved jungle soil, FYM and sand in 6:3:1 ratio. The plants were maintained in the nursery under filtered shade having 40 % day light. The plants were given regular nutritional and plant protection inputs as per the standard nursery package of practices (Anonymous, 2003). In the present study commercially important scions of three arabica cultivars such as S.795, Sln.10 and S.4202 have been grafted to three drought tolerant arabica cultivars *viz*., Sln.5B, Sln.9 and Sln.11 and two important robusta cultivars *viz*., C x R and S.274 rootstocks and had fifteen graft combinations. The grafting was carried out during the month of May by adopting wedge-cleft method using button stage seedlings (D'Souza *et al*.,1969). Before grafting, the button stage seedlings of rootstock and scion materials were dipped in 0.01% Carbendazim solution to prevent fungal attack. All the rootstock scion combinations were compared with eight self grafts of rootstock and scion materials and pure line seedlings of scion cultivars. The morpho-physiological parameters were studied using standard formulae. The data were analyzed using simple CRD described by Sundararaj *et al.* (1972). In each combination, thirty uniform plants were selected for observations and replicated three times. Pooled data was used for interaction studies in which six seedlings constituted per replication and replicated five times consisting of thirty plants per treatment. This was done to obtain minimum degrees of freedom. The interaction studies on all the parameters were restricted to have comparison between arabica/arabica, robusta/ arabica, self grafts and pure line seedlings of scion materials.

Classification of high, medium and low growth types was done by adopting Duncans Multiple Range Test (DMRT).

Results and Discussion

The results of the study indicated significant ($p<0.05$) differences in growth characteristics such as plant height, number of nodes, number of leaves, leaf area, primary branch production, internodal length and root length (Table 1). The rootstock scion combinations such as Sln.9/S.4202, Sln.5B/S.4202, Sln.5B/Sln.10, Sln.5B/S.795 Sln.11/Sln.10 and Sln.9/S.795 showed significantly ($p<0.05$) higher growth characteristics compared to rest of the combinations.

When the overall growth of rootstock scion combinations was analyzed in terms of leaf area ratio (LAR), relative leaf growth rate (RLGR), specific leaf area (SLA), specific leaf weight (SLW), leaf area duration (LAD), leaf area (LA), leaf weight (LW), absolute growth rate (AGR), relative growth rate (RGR) and net assimilation rate (NAR), significant ($p<0.05$) differences were observed (Tables 2 and 3). The combinations such as Sln.11/Sln.10, Sln.9/S.4202, Sln.5B/Sln.10, Sln.9/S.795, Sln.5B/S.4202 and Sln.5B/ S.795 have shown significantly higher AGR, SLW, LAR, RGR and RLGR indicating better growth rate. The NAR was significantly ($p<0.05$) high in S.274/ S.795, CxR/Sln.10, Sln.5B/Sln.10 and Sln.5B/S.4202 combinations. The total dry matter production (TDMP) reflects overall growth and development of plants. In the present investigation wide variations were observed with respect to TDMP between rootstock scion combinations. However, the arabica/arabica combinations such as Sln.5B/Sln.10, Sln.9/S.4202, Sln.11/Sl.10 and Sln.9/S.795 were found to be superior with respect of dry matter production (Table 3). Among self combinations, only Sln.11 and S.274 genotypes have shown significantly higher TDMP. The self rootstock combinations were poor with respect of overall growth compared to graft combinations with different rootstocks. These results indicated differential influence of rootstocks on scion materials. Such differential influence of rootstocks was reported earlier in rootstock scion combinations of coffee (Raghuramulu, 1994; Anonymous, 2005). Based on the results on morpho-physiological traits, the combinations such as Sln.9/S.4202, Sln.5B/S.4202, Sln.5B/Sln.10, Sln.11/Sln.10, Sln.5B/ S.795 and Sln.9/S.795 were grouped as high growth types (Table 4).

The observations on interaction effects indicated significantly ($p<0.05$) low plant height, number of nodes, number of leaves, internodal length, root length, LAR, LAD, LA, LW and TDMP grafted to robusta rootstocks compared to arabica rootstocks (Tables 5 and 6). The pure line scion seedlings have shown significantly ($p<0.05$) higher LAR and RLGR compared to rootstock scion combinations. However, the arabica/arabica combinations were on par with pure line seedlings with respect to SLA, SLW, LAD, LA and LW indicating arabica rootstocks were better for commercially important arabica scion materials. The dwarfing influence of diploid (2n=22) rootstock species on tetraploid (2n=44) species

like arabica coffee was well documented in coffee (Raghuramulu, 1994; Anilkumar and Srinivasan, 2001; Anon., 2005). This also confirms that the rootstocks with different genetic set up may have negative influence on compatibility and the vigour of scion materials (Hartmann and Kester, 1986).

The TDMP was significantly ($p<0.05$) low in robusta/arabica and self combinations compared to arabica/arabica combinations and pure line seedlings (Table 6). Such differences observed in rootstock scion combinations compared to pure line seedlings were in conformity with the reports of Naidu *et al*. (1992) and Raghuramulu (1994).

Table 1. Influence of root stock scion combinations on growth characteristics

Graft combination	Height (cm)	Nodes (no.)	Leaves (no.)	Primaries (no.)	Internodal length (INL) (cm)	Root length (RL) (cm)
Sln.9/S.795	49.8 cde	28 bcd	29 cd	6 c	4.0 cdf	21.4 de
Sln.9/Sln.10	36.5 ghi	21 ef	21 fg	3 f	3.3 efghi	21.2 de
Sln.9/S.4202	68.9 a	41 a	29 cd	8 a	3.6 efg	24.8 bcde
Sln.5B/S.795	53.0 bcde	25 de	23 ef	5 d	5.2 a	25.5 bcde
Sln.5B/Sln.10	57.5 bc	30 bc	34 bc	6 c	4.6 abc	31.8 a
Sln.5B/S.4202	59.7 b	27 bcd	27 de	5 d	4.8 ab	26.1 bcd
Sln.11/S.795	38.7 fgh	18 fg	17 ghi	2 g	4.9 ab	32.0 a
Sln.11/Sln.10	46.2 def	26 cd	34 bc	8 a	5.2 a	25.2 bcde
Sln.11/S.4202	30.3 hij	15 ghij	14 i	1 h	3.5 efgh	22.8 cde
CxR/S.795	56.3 bc	24 de	42 a	7 b	2.7 ijk	21.3 de
CxR/Sln.10	28.5 ij	17 fgh	21 fg	5 d	2.0 kl	22.0 de
CxR/S.4202	30.3 hij	17 fgh	21 fg	5 d	1.8 l	21.2 de
S.274/S.795	30.1 hij	16 ghi	22 fg	3 f	2.7 ijk	24.7 bcde
S.274/Sln.10	25.5 j	15 ghij	17 ghi	3 f	3.0 ghij	21.5 de
S.274/S.4202	23.0 j	17 fgh	20 fgh	4 e	2.8 hij	22.0 de
S.795/S.795	36.4 ghi	13 hijk	30 cd	5 d	1.8 l	21.0 de
Sln.10/Sln.10	53.8 bcd	17 fgh	28 d	5 d	3.2 fghij	20.3 e
S.4202/S.4202	50.4 cde	21 ef	20 fgh	3 f	4.4 bcd	27.5 abc
Sln.9/Sln.9	43.9 efg	10 k	20 fgh	2 g	3.8 def	28.0 abc
Sln.5B/Sln.5B	44.3 efg	11 jk	20 fgh	3 f	4.4 bcd	24.2 bcde
Sln.11/Sln.11	60.3 b	31 b	36 b	6 c	4.8 ab	28.1 ab
CxR/CxR	30.0 hij	12 ijk	15 hi	3 f	2.5 jkl	23.0 bcde
S.274/S.274	28.3 ij	10 k	19 fghi	3 f	2.7 ijk	25.8 bcd
Mean	42.7	20	24	4	3.5	23.5
CD (P=0.05)	7.09	3.41	4.01	0.75	0.57	3.80
CD (P=0.01)	9.32	4.48	5.27	0.98	0.75	5.00

Means with the same letter in a column do not differ significantly as per Duncan's Multiple Range Test at 5 per cent level of significance

The results also indicated adverse influence of robusta rootstocks on AGR and RGR of arabica scions (Table 6). The pure line seedlings have shown significantly ($p<0.05$) higher AGR and RGR and compared to rootstock scion combinations. These results confirm the earlier reports that grafting reduces certain growth traits in coffee (Raghuramulu, 1994). Ferwerda (1934) reported that the growth of robusta scions was not influenced by the vigour of the rootstocks. Nur (1984) observed differences in growth of scion on different rootstocks with regard to stem height, stem diameter, leaf area and dry weight.

Correlation analysis

Correlation analysis carried out to find out the relationship between the morpho-physiological parameters indicated significantly ($p<0.05$) positive relationship between SLA and AGR ($r=0.560$), NAR($r=0.498$), RLGR ($r=0.587$) among rootstock scion combinations (Table 7). Such relationships in coffee seedlings are well established in the earlier studies (Venkataramanan, 1985; Bhat, 2002; Mallikarjun, 2004).

Inverse relationship was observed between SLW and AGR($r=-0.535$) NAR ($r=-0.421$), RLGR ($r=-0.564$)

Table 2. Influence of root stock scion combinations on leaf physiological traits

Graft combination	Leaf area ratio (LAR) (dm^2g^{-1})	Relative leaf growth rate(RLGR) ($dm^2dm^2m^{-1}$)	Specific leaf area (SLA) (dm^2g^{-1})	Specific leaf weight (SLW) (gdm^2)	Absolute growth rate (AGR) ($g\ month^{-1}$)
Sln.9/S.795	4.18 bcde	0.049 fghi	1.47 bcd	0.68 bcd	1.28 bcd
Sln.9/Sln.10	3.89 de	0.039 ijkl	1.47 bcd	0.68 bcd	0.63 fg
Sln.9/S.4202	4.37 bcde	0.026 m	1.67 abc	0.60 cde	1.43 bc
Sln.5B/S.795	4.12 bcde	0.066 cd	1.60 abcd	0.63 cde	1.27 bcd
Sln.5B/Sln.10	3.54 ef	0.064 cde	1.62 abc	0.62 cde	1.31 bcd
Sln.5B/S.4202	3.84 de	0.056 defg	1.53 bcd	0.65 bcde	1.22 cde
Sln.11/S.795	4.03 de	0.043 hijk	1.40 bcd	0.71 bcd	0.78 f
Sln.11/Sln.10	6.00 a	0.054 efgh	1.61 abc	0.62 cde	1.48 b
Sln.11/S.4202	4.64 bcd	0.026 m	1.03 e	0.98 a	0.39 hi
CxR/S.795	2.72 f	0.070 bc	1.57 bcd	0.64 bcde	1.17 de
CxR/Sln.10	4.28 bcde	0.046 fghij	1.52 bcd	0.66 bcde	0.49 ghi
CxR/S.4202	3.94 de	0.045 ghijk	1.43 bcd	0.70 bcd	0.45 ghi
S.274/S.795	1.88 g	0.079 b	1.92 a	0.52 e	1.21 de
S.274/Sln.10	5.02 b	0.028 lm	1.60 abcd	0.63 cde	0.29 i
S.274/S.4202	4.09 cde	0.014 n	1.03 e	0.97 a	0.55 gh
S.795/S.795	3.90de	0.011 n	1.27 de	0.79 b	0.61 fg
Sln.10/Sln.10	4.63 bcd	0.034 klm	1.71 ab	0.58 de	1.27 bcd
S.4202/S.4202	4.07 cde	0.057def	1.40 bcd	0.71 bcd	1.04 e
Sln.9/Sln.9	2.96 f	0.056 defg	1.65 abc	0.60 cde	0.81 f
Sln.5B/Sln.5B	4.27 bcde	0.014 n	1.35 cd	0.74 bc	0.44 ghi
Sln.11/Sln.11	3.54 ef	0.112 a	1.64 abc	0.61 cde	1.85 a
CxR/CxR	4.66 bcd	0.037 jklm	1.48 bcd	0.68 bcd	0.34 hi
S.274/S.274	4.97 bc	0.035 jklm	1.48 bcd	0.67 bcde	1.25 cde
Mean	4.07	0.046	1.50	0.68	0.94
CD (P=0.05)	0.75	0.009	0.59	0.05	0.20
CD (P=0.01)	NS	NS	0.78	NS	NS

Means with the same letter in a column do not differ significantly as per Duncan's Multiple Range Test at 5 per cent level of significance

NS= Not significant

and SLA (r =-0.980) indicating increase in SLW during normal conditions reduce the overall leaf growth of rootstock scion combinations. However, leaf area duration (LAD) showed highly ($p<0.01$) positive relationship (r=0.753) with AGR indicating LAD also governs the growth in graft combinations of coffee.

Studies on leaf area (LA) indicated positive relationship with AGR (r=0.821), RLGR (r=0.506), SLA (r=0.429) and LAD (r=0.969) but inverse relationship with SLW (r= -0.450). These results indicated that higher the SLW lower is the LA and under reduced growth SLW increases in coffee graft combinations. The root length (RL) did not show any significant relationship with AGR, NAR, LAR, SLA, SLW and LAD but interestingly positive ($p<0.05$) relationship (r=0.461) with leaf area, relative leaf growth rate(r=0.430) and leaf weight(r=0.448). The root length may be having a role in improving the leaf growth in coffee plants probably by deep soil water harvesting capacity indicating importance of root length in coffee plants. Similar observations between plant height and root depth was observed in rice by Armenta-Soto *et al*. (1983) and Ekanayake *et al*. (1985) and in Tef by Ayele *et al*. (2001). Similar relationships between root traits and leaf morphological traits were also reported in coffee seedlings (Venkataramanan, 1985; Bhat, 2002; Mallikarjun, 2004).

The cumulative results of the rootstock scion interaction studies based on growth characteristics, leaf growth analysis traits and growth analysis traits indicated

that at the age of eighteen months, the pure line seedlings of scion materials maintained comparatively higher vigour compared to rootstock scion combinations. Among combinations, arabica/arabica combinations performed better and on par with seedlings in many growth characteristics. The self combinations did not perform better compared to pure line seedlings with respect to growth and development. Arabica stocks were better than robusta stocks for arabica scions studied in this programme. The results also indicated that the genetically divergent rootstocks of same species are better to achieve desirable growth of scion materials in coffee. Based on

Table 3. Influence of Root stock scion combinations on leaf and growth analysis traits

Graft combination	Relative growth rate (RGR) ($g\ g^{-1}\ month^{-1}$)	Net assimilation rate (NAR) ($g\ dm^2\ month^{-1}$)	Leaf area duration (LAD) (days)	Leaf area (LA) (cm^2)	Leaf weight (LW) ($g\ plant^{-1}$)	Total dry matter production (TDMP) ($g\ plant^{-1}$)
Sln.9/S.795	0.049 defg	0.012 def	658 bc	872 b	5.91 b	20.75 ab
Sln.9/Sln.10	0.031 j	0.008 g	446 fg	554c	3.76 c	13.03def
Sln.9/S.4202	0.058 cd	0.013 de	585 cd	658c	3.93 c	21.42 ab
Sln.5B/S.795	0.081 b	0.020 b	424 fg	608 c	3.81 c	17.08 bcd
Sln.5B/Sln.10	0.045efghi	0.013 de	669 bc	952 b	5.89 b	22.08a
Sln.5B/S.4202	0.065 c	0.017 c	445 fg	611 c	3.99 c	17.49 bcd
Sln.11/S.795	0.039 ghij	0.010 efg	462 efg	592 c	4.22 c	14.05def
Sln.11/Sln.10	0.069 c	0.011 defg	797 a	1084 a	6.73 a	20.94 ab
Sln.11/S.4202	0.043 fghij	0.009 fg	230 ijk	257 e	2.51 fg	6.78 fghij
CxR/S.795	0.057cde	0.021 b	373 gh	543 c	3.46 cde	17.67 bcd
CxR/Sln.10	0.040 fghij	0.009 fg	308 hi	400 d	2.63 f	8.77 efgh
CxR/S.4202	0.035 hij	0.009 fg	299 hi	385 d	2.69 ef	8.74 efgh
S.274/S.795	0.059 cd	0.032 a	275 ij	413 d	2.15 fgh	18.09 bcd
S.274/Sln.10	0.045 efghi	0.009 fg	175 k	200 e	1.25 i	4.84 fghij
S.274/S.4202	0.039 ghij	0.010 efg	301 hi	300 de	2.90 def	9.95 efgh
S.795/S.795	0.052 def	0.013 de	238 ijk	228 e	1.80 ghi	9.54 efgh
Sln.10/Sln.10	0.065 c	0.014 d	502 def	600 c	3.50 cd	18.20 bcd
S.4202/S.4202	0.091 b	0.022 b	290 hi	400 d	2.85 def	13.60def
Sln.9/Sln.9	0.033 ij	0.011 defg	452 fg	622 c	3.76 c	16.24 cde
Sln.5B/Sln.5B	0.034 ij	0.008 g	295 hi	293 de	2.16 fgh	8.73 efgh
Sln.11/Sln.11	0.106 a	0.030 a	548 de	874 b	5.33 b	20.49 ab
CxR/CxR	0.048 defg	0.010 efg	184 jk	225 e	1.52 hi	5.49 fghij
S.274/S.274	0.047 defgh	0.009 fg	738 ab	890 b	6.00 b	20.5 ab
Mean	**0.054**	**0.014**	**422**	**546**	**3.60**	**14.68**
CD (P=0.05)	**0.010**	**0.003**	**61**	**96**	**0.63**	**2.84**
CD (P=0.01)	**NS**	**NS**	**81**	**127**	**0.82**	**3.74**

Means with the same letter in a column do not differ significantly as per Duncan's Multiple Range Test at 5 per cent level of significance

NS = Not significant

Table 4. Classification of rootstock scion combinations based on growth characteristics at the age of 18 months

High growth types	Sln.9/S.4202, Sln.5B/S.4202, Sln.5B/Sln.10, Sln.5B/S.795 Sln.11/Sln.10, Sln.9/S.795
Medium growth types	S.274/S.795, CxR/S.795
Low growth types	Sln.9/Sln.10, Sln.11/S.795, Sln.11/S.4202, CxR/ Sln.10, CxR/S.4202, , S.274/Sln.10, S.274/S.4202

the influence of rootstocks on morpho-physiological traits it could be concluded that the Sln.9 and Sln.5B rootstocks for S.4202 scion, Sln.5B and Sln.11 rootstocks for Sln.10 scion and Sln.9 and Sln.5B rootstocks for S.795 scion found to be efficient and could be field evaluated to improve coffee crop production.

References

Anilkumar and Srinivasan, C.S.1999. Grafting and its practical utility in coffee plantations. *Indian Coffee.* **12** (3):3-6.

Anilkumar and Srinivasan, C.S.2001. Studies on the influence of rootstocks on compatibility and initial growth of scion in Cauvery and S.795 cultivars. *J. Coffee Res*. **29**(1&2): 68-77.

Table 5. Rootstock scion interaction effect on growth characteristics

Graft combination	Height (cm)	Nodes (no.)	Leaves (no.)	Primaries (no.)	Internodal length (INL) (cm)	Root length (RL) (cm)	Specific leaf area (SLA) (dm^2g^{-1})	Specific leaf weight (SLW) (gdm^2)
Arabica/Arabica	48.9	25.7	25.1	4.8	6.5	23.4	1.49	0.68
Robusta/Arabica	32.3	17.7	23.8	4.4	2.5	22.1	1.51	0.68
Self	43.4	15.6	23.3	3.7	3.4	24.7	1.50	0.67
Seedlings	56.2	32.2	30.5	5.0	6.8	24.8	1.52	0.67
Mean	45.2	22.8	25.7	4.5	4.8	23.7	1.51	0.68
CD (P=0.05)	4.1	2.1	2.3	0.4	0.5	2.2	NS	NS
CD (P=0.01)	5.7	3.0	3.2	0.6	0.6	3.1	NS	NS

NS= Not significant

Table 6. Rootstock scion interaction effects on leaf physiological traits and dry matter production

Graft combination	Leaf area ratio (LAR) (dm^2g^{-1})	Relative leaf growth rate (RLGR) ($dm^2\ dm^2\ m^{-1}$)	Lead area duration (LAD) (days)	Leaf area (LA) (cm^2)	Leaf weight (LW) (g $plant^{-1}$)	Total dry matter production (TDMP) (g $plant^{-1}$)	Absolute growth rate (AGR) (g $month^{-1}$)	Relative growth rate (RGR) (g $g^{-1}month^{-1}$)
Arabica/Arabica	4.29	0.047	524	688	4.53	17.1	1.087	0.053
Robusta/Arabica	3.65	0.047	289	374	2.51	11.4	0.693	0.046
Self	4.13	0.044	406	516	3.37	14.5	0.950	0.060
Seedlings	5.02	0.053	550	718	4.71	18.0	1.260	0.062
Mean	4.27	0.048	442	574	3.78	15.25	0.998	0.055
CD (P=0.05)	0.38	0.004	41	52	0.34	2.5	0.089	0.005
CD (P=0.01)	0.52	0.006	56	72	0.47	3.7	0.123	0.007

Table 7. Correlation analysis between the morpho-physiological traits in rootstock scion combinations of coffee

Parameters	AGR (g $month^{-1}$)	RGR (g g^{-1} $month^{-1}$)	NAR (g dm^2 $month^{-1}$)	LAR (dm^2g^{-1})	RLGR ($dm^2\ dm^2\ m^{-1}$)	SLA (dm^2g^{-1})	SLW (gdm^2)	LAD (days)	LA (cm^2)	LW (g $plant^{-1}$)
SLA	0.560**	0.323	0.498*	-0.304	0.587**					
SLW	-0.535**	-0.308	-0.421*	0.238	-0.564**	-0.979**				
LAD	0.753**	0.199	-0.004	0.241	0.291	0.337	-0.365			
LA	0.821**	0.322	0.161	0.121	0.506*	0.429*	-0.452*	0.969**		
LW	0.748**	0.254	0.056	0.189	0.408	0.231	-0.261	0.966**	0.976**	
RL	0.385	0.222	0.220	-0.160	0.430*	0.197	-0.210	0.386	0.461*	0.448*

*p value=0.05

** p value=0.01

Anil Kumar., Ramamurthy, N., Muralidhara, H.R. and Srinivasan, C.S. 2003. Interspecific grafting and its influence on yield, bean quality, caffeine content and nutrients uptake of arabica scion cultivars. *J. Coffee Res.* **31**(1): 76 - 94.

Anonymous, 2003. Coffee Guide. Research Department. Coffee Board, India. 180 p.

Anonymous, 2005. Annual Detailed Technical Report. Research Department, Coffee Board, India. **58**: 60-62.

Armenta-Soto, J., Chang, J.T., Loresto, G.C. and O' Toole, J.C.1983. Genetic analysis of root characters in rice *(Oryza sativa* L.) Soc Adv Breeding Res. *Asia Oceania J.* **15**:103-116.

Ayele, M., Blum.A. and Nguyen,H.T.2001. Diversity for osmotic adjustments and root depth in Tef. (*Eragrostis tef* (Zucc) Trotter), *Euphyytica* **121**:237-249.

Bhat, P.R. 2002. Phenotyping and molecular analysis of Coffea arabica L. accessions and mapping population to identify RAPD markers associated with root characteristics and associated physiological traits. *Ph.D Thesis*, University of Agricultural Sciences, Bangalore, India.180 p.

D' Souza, G.I., Shamanna, H.V. and Kumar, A.C.1969. Control of coffee nematodes in South India - A progress report. *Indian Coffee* **33**(4): 129.

Ekanayake, I.S., O' Toolle, J.C., Garrity, D.P. and Masajo, T.N.1985. Inheritance of root characteristics and their relations to drought resistance in rice. *Crop Sci.* **25**:927-933.

Fahl,J.I., Carelli, M.I.C., Gallo, P.B., Costa, W.M. and Novo. 1998. Efeito da enxecrtia de *Coffeea arabica* sobre C. Canephora and C. Congenisis no crescimento, nutricio mineral e na prodeecao da plants. *Bragantia* **57**: 297 - 312.

Fahl , J.I., Carelli, M.L.C., Menezs, H.C., Gallo, P.B. and Trivelin, P.C.O. 2001. Gas exchange, growth, yield and beverage quality of *Coffea arabica* cultivars grafted on *Coffea canephora* and *Coffea cogenesis*. *Expt. Agri.* **37**(2): 241-252.

Ferwerda, F.P. 1934.The vegetative propagation of coffee. *Emp.J.Exp.Agric*. **2**(7):189-199.

Hartmann, H.T. and Kestar, D.E. 1986. *Plant propagation principals and practices*. pp. 377-388. (4th Edn). Prentice Hall of India Pvt. Ltd, New Delhi.

Mallikarjun, G.A 2004. Molecular markers for root traits, WUE and associated physiological traits in *Coffea canephora* Pierre ex. Froehner. *Ph.D. Thesis*, University of Agricultural Sciences, Bangalore, India. 196 p.

Naidu, M.M., Muniswamy, L. and Sreenath, H.L. 1992. Comparison of seedlings vigour in three clones of *Coffea canephora. J Coffee. Res.* **22**(2): 131-134.

Nur, A.M.1984. Pengaruh batang babaw terhadap pertumbuhan dan Komposisi mineral daun pada Kopi robusta. *Menera Perkebunan* **52**(3): 65- 70.

Raghuramulu, Y. and Purushotam, K. 1987. Rootstock trials in coffee. I. Studies on success in grafting and stionic influences on growth of plants in some graft combinations. *J. Coffee Res.* **17**(2): 8 -15.

Raghuramulu, Y. 1994. Evaluation of rootstocks for arabica coffee scions for compatibility, vigour and tolerance to drought and root - lesion nematodes. *Ph.D. Thesis*, University of Agricultural Sciences. Bangalore, India. 176p.

Sundararaj, N., Nagaraju, S., Venkataramu, M.M. and Jagannath, M.K. 1972. *Design and analysis of field experiments.* 419 pp. Univ. Agric. Sci., Bangalore.

Tubbs, F.R. 1973. Research fields in the interaction of rootstocks and scions in woody perennials. *Hort. Abst.* **43**(5): 247-253.

Venkataramanan, D.1985. Physiological studies in coffee. *Ph.D. Thesis*, University of Mysore, India. 157 p.