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VARIABILITY IN NET PHOTOSYNTHETIC RATE, WATER USE EFFICIENCY AND CARBOXYLATION EFFICIENCY OF TOBACCO VARIETIES

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Increasing the photosynthetic efficiency is one of the most important ways to increase productivity. Understanding the variability in net photosynthetic rate and related traits among germplasm helps in selecting parents in breeding programmes. In the present study, 90 released varieties of different tobacco types were grown in experimental plots with recommended package of practices at the CTRI Research Farm, Katheru, East Godavari district, Andhra Pradesh were assessed for net photosynthetic rate (Pn), transpiration rate (E), stomatal conductance (SC) and intercellular CO_2 concentration (Ci). From these observations intrinsic and instantaneous water use efficiency and carboxylation efficiency were computed. Non-FCV tobacco varieties recorded greater net photosynthetic rate and related traits compared to FCV tobacco varieties. The Photosynthetic rate (Pn) of FCV tobacco varieties varied from 8.95 to 28.80 mmol/m²/s with a mean of 18.61 mmol/m²/s. Among the non-FCV tobacco varieties Pn varied from 9.7 to 35.84 mmol/m²/s with a mean of 23.50 mmol/m²/s. Instantaneous water use efficiency varied between 2.330 to 4.930 µmol/mol among FCV tobacco varieties and 1.770 to 5.42 µmol/mol in non-FCV tobacco varieties with a mean of 3.23 and 3.557 µmol/mol, respectively. Mean intrinsic water use efficiency of FCV and non-FCV tobacco varieties were 68.69 and 71.86 µmol/mmol, respectively. Carboxylation efficiency ranged from 0.036 to 0.137 µmol/m²/s²/(µl/l) in FCV and 0.037 to 0.160 µmol/m²/s²/(µl/l) in non-FCV tobacco varieties. Among FCV tobacco varieties, Kanchan, Siri and Sahyadri recorded higher Pn, instantaneous and intrinsic water use efficiency and intrinsic carboxylation efficiency whereas, varieties *viz.*, GCT-3, DD 437, GCT-2, HD-65-40, DP-401 and Bhagyalakshmi recorded higher efficiency among non-FCV tobacco varieties. The varieties which recorded greater photosynthetic rate, water use efficiency and carboxylation efficiency can be used in evolving physiologically efficient high productive varieties.

Key words: Photosynthetic rate, Water use efficiency, Tobacco varieties

INTRODUCTION

Tobacco is an important commercial crop grown in widely varying soil and climatic conditions in the country. It is a low-volume and high-value cash crop significantly contributing to the economy of the nation. Most of the commercial tobaccos produced in the world are *Nicotiana tobacum* sp. The only other species cultivated on a limited scale is *N. rustica.* In addition to the botanical classification of the species, based on method of curing tobacco varieties are classified as flue-cured Virginia (FCV) and non- FCV (burley, chewing, cigar, hookah, cheroot, *bidi*, *natu*) types. Since the inception of CTRI, 90 varieties belonging to different types of tobacco were released. In many of the breeding programmes, one of the parents was a released variety. Hence, it is planned to study the variability in net photosynthetic rate and related traits in released varieties of FCV and non-FCV tobacco.

MATERIALS AND METHODS

The experimental material used for this study was 90 released varieties of different tobacco types (FCV and Non-FCV) and grown in experimental plots with common package of practices at CTRI Research Farm, Katheru, East Godavari district, Andhra Pradesh. The released varieties of FCV (29) and non-FCV tobacco (61) varieties used for the study are given below.

FCV tobacco varieties (29) included Harrison Spl, Chatam, Delecrest, Hicks, Virginia gold, Dhanadayi, Kanakaprabha, CTRI Spl, CTRI Spl-MR, Jayasri, Jayasri-MR, Godavari Spl, Hema, Gauthami, VT-1158, 16/103, Mc Nair-12, CM-12, Kanchan, Kanthi, Swarna, Bhavya, Ratna, Thrupti, FCV Spl, Hemadri, Siri, N-98 and Sahyadri.

Non-FCV (61) tobacco varieties included Burley-21, Banket A-1, BSRB-2, HDBRG, Prabhat, Viswanath, *Natu* Spl, Pyruvittanam, NG-73, Bhairavi, DR-1, *Lanka* Spl, Sendrapatty Spl, Bhavani Spl, Sangami, Krishna, Dixie shade, S-5, Olor, Thangan, Bhagyalakshmi, Maragadham, Vairam, Meenakshi, Meenakshi-CR, Abirami, DP-401, Gandakbahar, Sona, Prabha, PT-76, Vaishali Spl, Lichavi, GT-9, GT-7, GT-5, GT-4, Anand-2, Anand-119, ABT-10, NPN-190, Bhavyasree, Bhagyasree, Veda Ganga, GT-6, GT-8, Anand-145, GC-1, GCT-2, GCT-3, DD-437, HD 65-40, Dharla, Jatichama, Jati Podali, Manasi, Azad Kanchan, Hemti, Bitri, Torsa and DCT-4.

During crop growth, at 60 days after planting observations on net photosynthetic rate (Pn), transpiration rate (E), stomatal conductance (Sc) and intercellular CO_2 concentration (Ci) were recorded using portable photosynthetic system (LICOR-6400-40 model) on first fully formed leaf from the top. From the observations intrinsic and instantaneous water use efficiency (WUE) and carboxylation efficiency were computed. Correlations were worked out among the different parameters.

RESULTS AND DISCUSSION

Variability in net photosynthetic rate, stomatal conductance, transpiration rate, intercellular CO_2 concentration and related traits of FCV and non-FCV tobacco varieties were presented in Table 1. Non-FCV tobacco varieties recorded higher values in all the traits compared to FCV tobacco varieties.

Photosynthesis is the key to dry matter production and increasing the photosynthetic efficiency is the most important way of increasing productivity (Gupta, 1994). Of all aspects of plant metabolism, photosynthesis shows the most prominent variation under the dictates of the immediate environment (Arora and Gupta, 1996). The values of net photosynthetic rate recorded in FCV and non-FCV tobacco varieties are presented in Fig. 1. The varieties which recorded greater than mean value are considered as efficient varieties. Among FCV tobacco varieties Kanchan, Harrison Spl, Thrupti. FCV Spl, Siri, Bhavya, Swarna, N-98, Ratna,Jayasri, Jayasri-MR and Sahyadri recorded Pn greater than 18.61 µmol/m^2/s (mean of 29 FCV tobacco varieties) and found efficient compared to other varieties. Among non-FCV tobacco varieties, Krishna, Bharavi, *Lanka* Spl, Sangami, Sendrapatty Spl, PP-437, Viswanath, Meenakshi, DR-1, Dharla, Vairam, BSRB-2, GCT-2, NPN-190, *Natu* Spl, HD-65-40, Anand-145, DCT-4, Prabhat, Lichhavi, Sona, GT-5, Pyruvittanam, Thangan, DD-401, Bhagyalakshmi, GT-4, Cocker-1 and GT-6 recorded Pn values higher than

Table 1: Variability in net photosynthetic rate, stomatal conductance, transpiration rate and related traits among the varieties of FCV and non-FCV tobacco

Physiological parameters	FCV varieties			Non-FCV varieties		
	Range	Mean	SD	Range	Mean	SD
Net photosynthetic rate (µmol/m^2/s)	8.950 - 28.80	18.61	5.169	9.70 - 35.84	23.50	5.44
Stomatal conductance (mol/m^2/s)	0.126 - 0.527	0.279	0.093	0.135 - 0.589	0.343	0.113
Transpiration rate (m mol/m^2/s)	2.730 - 9.540	6.000	2.037	2.830 - 10.94	6.85	1.91
Instantaneous WUE (µmol/mol)	2.330 - 4.930	3.230	0.618	1.770 –5.42	3.56	0.787
Intrinsic WUE (µmol/mmol)	50.15 - 91.51	68.69	11.602	46.41 - 120.3	71.86	15.10
Intrinsic Carboxylation efficiency [(µmol/m^2/s^2/(µl/l)]	0.036 - 0.137	0.077	0.0241	0.037 -0.160	0.100	0.024

the mean value of 61 varieties (23.50 µmol/ m^2/s).

Measurement of WUE might be a useful trait for selecting genotypes with improved drought adaptation and biomass productivity under different environmental conditions (Li, 2000). Instantaneous WUE is estimated as the ratio of net photosynthetic rate to transpiration (Petite *et al.*, 2000). Higher the value, better the efficiency of the plant to divert water for photosynthesis than transpiration. Instantaneous WUE varied between 2.33 to 4.93 µmol/mol among FCV tobacco varieties and 1.77 to 5.42 µmol/mol in non-FCV tobacco varieties with a mean of 3.23 and 3.56 µmol/mol, respectively (Fig. 2). FCV tobacco varieties, Delcrest, Chatam, Virginia gold, Harrison Spl, Hicks, Kanchan, CTRI Spl, Kanakaprabha, Kanthi, Sahyadri, Dhanadayi, Jayasri-MR, CTRI Spl and Jayasri recorded higher instantaneous WUE and varieties *viz.*, GT-8, Bhagyasree, GC-1, DP-401, Maragadham, GCT-3, DD-437, Meenakshi-MR, Bharavi, *Lanka* Spl, Krishna, Olor, Jati Chama, GCT-2, S-5, Veda Ganga, Sangami, DR-1, Bhagyalakshmi, Jati Podali, Thangan, Manasi, Abirami, PT-76, Bhavani Spl, Dixie shade, HD-65-40, Anand-119, Sendrapatty Spl, Lichhavi and GT-5 recorded higher values among non-FCV tobacco varieties.

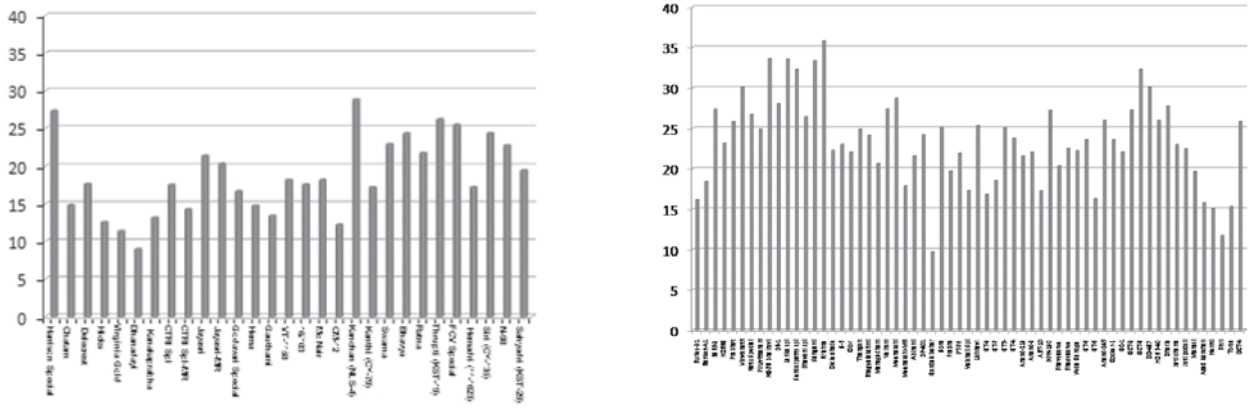
The ratio of net photosynthetic rate to stomatal conductance is referred as intrinsic WUE (Ares and Fownes, 1999) and it implies the inherent ability of the plant to assimilate CO_2. Higher the ratio, better the ability for carbon assimilation. FCV tobacco varieties Sahyadri, Hemadri, Kanti, Kanchan, Delcrest, Siri, Virginia Gold, Kanaka Prabha, CTRI Spl, Hicks, N-98, Dhandayi, Thrupti, FCV Spl and Chetam recorded higher values than mean value among FCV tobacco varieties and considered as efficient for carbon assimilation. It ranged from 50.51 - 90.51 µmol/mmol with a mean of 68.69 µmol/mmol (Fig. 3). Among non-FCV tobacco varieties, GT-8, Bhgyasree, GC-1, Margadham, Veda Ganga, GCT-3, Azad Kanchan, Bitri, DD-437, Manasi, Jati Chama, GCT-2, Jati Podali, Olor, ABT-10, HD-65-40, DP-401, BSRB-2, PT-76, NPN-190, GT-7, S-5, Anand-119, Meenakshi-MR, HDBRG, Viswanath, Torsa, Bhagyalakshmi recorded higher than 71.86 µmol/mmol which is the mean of 61 non-FCV tobacco varieties.

The ratio of net photosynthetic rate to intercellular CO_2 concentration is termed as intrinsic carboxylation efficiency (Hamerlynck *et al.*, 2000). Higher the ratio, better the efficiency for carboxylation. Intrinsic carboxylation efficiency ranged from 0.036 to 0.137 µmol/m^2/s^2 /(µl/l) with a mean of 0.077µmol/m^2/s^2/(µl/l) among FCV tobacco varieties *viz.*, Kanchan, Siri, Thrupti, FCV Special, Harrison Spl, Bhavya, N-98, Sahyadri, Swarna, Ratna, Hemadri, Jayasri, Dlcrest, CTRI Spl and 16/103 recorded greater values than mean value. Among non-FCV tobacco varieties GCT-3, DD-437, Krishna, Bhagyasree, Viswanath, *Lanka* Spl, Bhairabvi, Sangami, GCT-2, NPN-90, BSRB-2, GC-1, Sendrapatty Spl, Dharla, HD-65-40, *Natu* Spl.,Ved Gandga, DCT-4, Prabhat, GT-5, Pyruvittanam, Meenakshi, Lichhavi, Jati Chama, DR-1, Thangan, DP-401, Bhavani Spl, Bhagyalakshmi, HDBRG, GT-8 and Jati Podali recorded higher values compared to mean value of (0.100 µmol/m^2/s^2/(µl/l). The variation among these varieties ranged from 0.037 to 0.160 µmol/ m^2/s^2/(µl/l) (Fig. 4).

From the results of all traits, it was found that FCV tobacco varieties Kanchan, Siri and Sahydri and non-FCV tobacco varieties *viz.*, GCT-3, DD-437, GCT-2, HD65-40, DP-401 and Bhagyalakshmi recorded higher Pn, instantaneous and intrinsic WUE and intrinsic carboxylation efficiency.

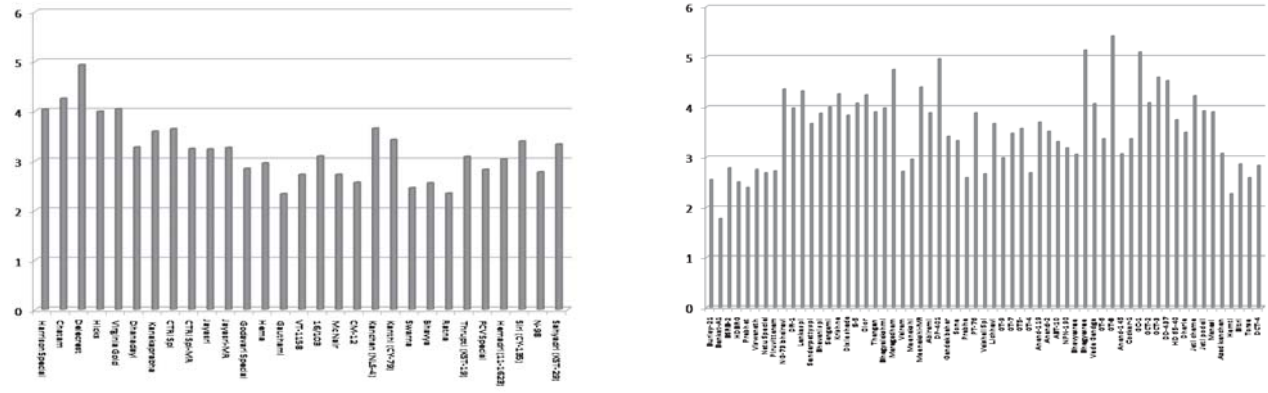
Correlation matriicisamong different gas exchange parameters and related traits are presented in Table 2. Pn is positively correlated with Sc, E and Intrinsic carboxylation efficiency and no correlation with Ci and instantaneous and intrinsic WUE. E is positively correlated with Pn, Sc, Ci. Intrinsic WUE is positively correlated with instantaneous WUE and is negatively correlated with Sc, Ci and Sc, Ci and E. The correlations clearly denoted that all these traits were interdependent and denotes efficiency of the varieties to produce biomass by using water effectively.

From the results it can be concluded that the varieties which recorded greater photosynthetic rate, water use efficiency and carboxylation



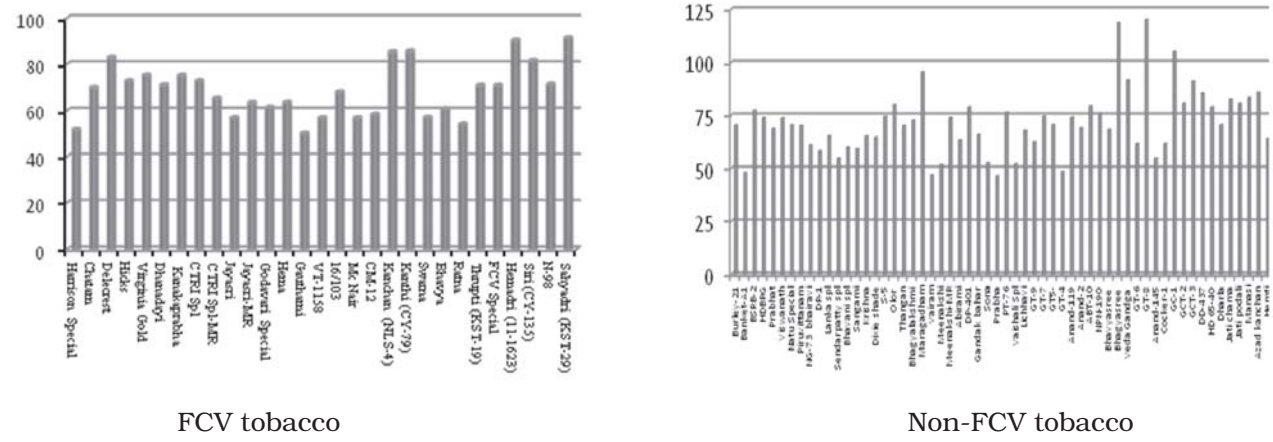
FCV tobacco Non-FCV tobacco

Figure 1: Variability in net photosynthetic rate (µmol/m^2/s) among different FCV and non-FCV tobacco varieties



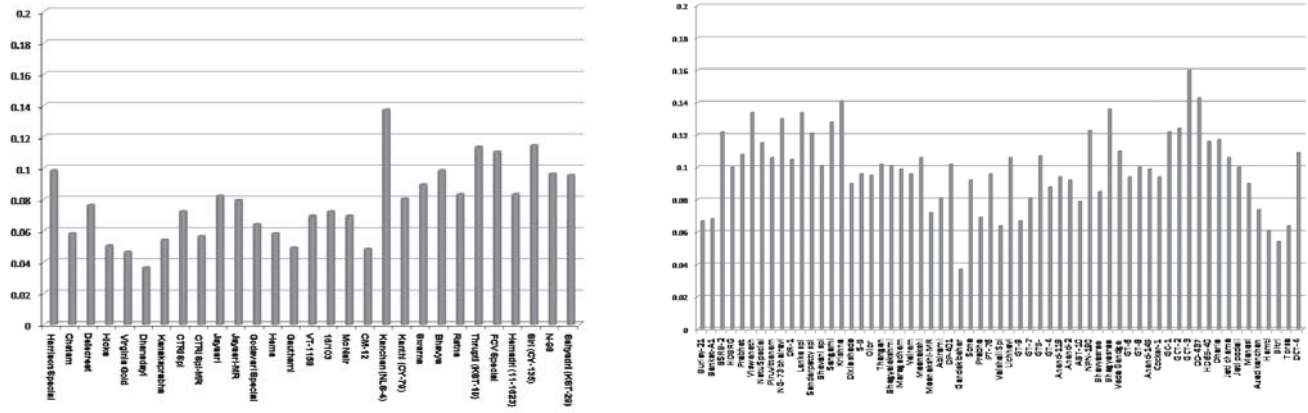
FCV tobacco Non-FCV tobacco

Figure 2: Variability in Instantaneous WUE (µmol/m) among different FCV and non- FCV tobacco varieties



FCV tobacco Non-FCV tobacco

Figure 3: Variability in Intrinsic WUE ((µmol/mmol)among different FCV and non-FCV tobacco varieties



FCV tobacco Non-FCV tobacco

Figure 4: Variability in Carboxylation efficicency (µmol/m²/s² /(µl/ l) among different FCV and non-FCV tobacco varieties

Table 2: Correlation matrix among different gas exchange parameters

Parameter	Pn	SC	Ci	E	Instantaneous WUE	Intrinsic WUE	Intrinsic CE
Pn	1.00	0.822**	-0.001	0.681**	0.188	-0.089	0.915**
SC		1.000	0.527**	0.773**	-0.153	-0.600**	0.542**
Ci			1.000	0.306**	-0.497**	-0.968**	-0.394**
E				1.000	-0.153	-0.469**	0.503**
Instantaneous WUE					1.000	0.618**	0.371**
Intrinsic WUE						1.000	0.300**
Intrinsic CE							1.000

efficiency can be used in evolving physiologically efficient high productive varieties.

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