Research Article

Morphogenetic Analysis of Different Flue Cured Virginia (FCV) Exotic Hybrid Varieties

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Abstract | A trial of Flue-Cured Virginia (FCV) hybrid varieties was evaluated for morphogenetic and disease-resistant characteristics during 2019-2020. It was conducted in a randomized complete block design (RCBD) with three replications of seven varieties (PVH-1600, PVH-2275, PVH-2340, PVH-2324, PVH-2329, SPT-G-28, and K-399). The plant height, leaf dimensions, green leaves, cured leaves weight, nicotine, and reduced sugar contents were examined. Analysis showed highly significant differences (P>0.01) among varieties for examined traits. The maximum number of green leaves (28), was produced by PVH-2324 at first picking, while PVH-1600 showed the maximum number of leaves (22), leaf area (1241cm^2), green leaves (29.3 Kg) and cured leaves weights per plot (4.6 Kg). Furthermore, PVH-1600 and K-399 showed the maximum mean values for green leaves (0.97 Kg) and cured leaves (0.227 Kg) weights respectively. The tallest plant was identified as PVH-2324 (136.21 cm). Genotype PVH-2329 revealed the maximum amount of reducing sugar (15.83%) compared to other PVH varieties. Moreover, the highest nicotine (2.91 %) content was found in K-399. From the present study, it is concluded that PVH-1600 and PVH-2329 varieties showed the best performance as compared to other promising hybrids for most of the important parameters under study. Therefore, these genotypes are recommended for future cultivation in the agro-climatic conditions of Mardan.

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Introduction

Tobacco (*Nicotiana tabacum* L.) belongs to the family Solanaceae, one of the non-food commodities present worldwide. *Nicotiana tabacum* and *Nicotiana rustica* are widely cultivated for their commercial uses in different parts of the world (Kamal *et al.*, 2017). The tobacco industry employs over 100

million people in various parts of the world. Tobacco is the main source of Flue-Cured Virginia (FCV), mostly grown in north-western parts of Pakistan.

Most countries produce a growing manufacturing tobacco industry, playing an important role in industrial and economic development. Tobacco is a tall green verdant yearly plant cultivated in a warm environment in South and Central America. However, currently, the crop is domesticated in around 100 countries in the world. As a cash crop, it is a significant and solid revenue-generating source that has added to farmer welfare (Keyser, 2002; Tang *et al*., 2020).

The yield of tobacco crops is higher in Pakistan compared to other countries including China, India, Brazil, America and Greece but unfortunately, the quality is substandard and does not meet the great cost in the international market (Badshah, 2005). The evaluation of leaf quality depends on the relative concentration of various organic and inorganic constituents (Tso, 1990). Tobacco is one of hardly any plants going into the world market completely on a leaf basis and is most usually developed for the business of non-food items (Lewis, 2020). The leaf is the major economic part of the tobacco crop, which is harvesting and processing for the cigarette industry (Yousafzai *et al*., 2006; Song *et al*., 2007). On the other side, Nicotine is a valuable component, and its concentration increases with the age of the plant. A mature tobacco plant possesses about 64% nicotine in its leaves, 18% in the stem, 13% in the root, and 5% in the flower (Weil and Rosen, 1993; Fei *et al*., 2019).

To improve the yield of tobacco, it is important to know the characteristics of each variety used for tobacco production, including the number of leaves per plant, plant height, different genotypes, and so on. The yield of tobacco can be increased by various approaches. The most promising choice is the selection of a suitable variety with maximum productivity in specific agro-climatic conditions (Alkhatib *et al*., 2019; Hussain *et al*., 2023). The farmers are getting a low yield of tobacco in contrast to different nations of the world, which is due to the lack of selection of a promising tobacco variety. The farmers rely on a few standard varieties to fulfill their economic requirements. Those varieties should be cultivated that give maximum yield concerning the regional agro-climatic conditions (Butorac *et al*., 2004), and expectantly this practice will significantly increase yield. Pakistan tobacco board is taking a stab by importing seeds from other tobacco-producing countries to boost the economy. Seeds that produce maximum yield and high-quality leaves will bring high profit to the farmers and will improve the fares of tobacco and its products. Furthermore, to improve tobacco yield it is important to monitor the various features of the tobacco plant like plant height, yield, and green and cured leaves weight. For this tending, a varietal trial was performed to investigate the performance of seven different tobacco profigen hybrid varieties (PVH). These PVH varieties were also investigated for their morpho-agronomic quality traits, disease-resistant, and to identify the most suitable hybrid for the local agro-climatic conditions.

Materials and Methods

This experiment was performed at Tobacco Research Station Khan Garhi, Mardan, situated southwest of district Mardan (Altitude of 283 meters). Seven different varieties of tobacco namely PVH-1600, PVH-2275, PVH-2275 and PVH-2324 whose seed origin from Brazil/Profigen, SPT-G-28/Scotland from Speight Seed Company), and K-399/Novartis seed from Hoke, were evaluated for important traits. The experiment was laid out in randomized block design (RCBD) with three replications. Spatial courses of action were finished utilizing 90cm row-to-row and 60 cm plant-to-plant separation. A basal dose of fertilizer at the rate of 60 Kg of nitrogen, 80 Kg of phosphorus, and 80 Kg of potash per hectare was applied in the form of NPK complex and was administered by placement method after one week of transplantation. Normal practices of intercultural and insect control were adopted. The data were recorded on all parameters of the selected varieties and were analyzed statistically by using Statistics 8.1 software.

Nursery management

Tobacco seeds of 7 different tobacco genotypes were sown on 11th December 2019 with a seed rate of 4-5 gm per hectare. The bed size was 10m long and 1m wide. Thinning was done 4-5 times from 15 to 20 January from each bed.

Field management

Before transplantation, the soil was prepared through a cultivator and rotator. Healthy and viable seedlings were transplanted into the field in March 2019 and on the third day of transplantation, water was

supplied to establish the profuse rooting system. The plant was irrigated 4-6 times during the growing season. Various fertilizers were uniformly applied to the field including N: P: K and DAP. NPK which contains Nitrogen, Phosphorus, and Potassium. DAP is the most popular phosphate fertilizer with a high nutrient content and better physical properties. The composition of DAP is 18% nitrogen and P205 46%. Both fertilizers were applied at the rate of 75:75:75 Kg per Hectare. Each plot was measured into 6 x 2 feet (ft) with five rows, having 10 plants in each row. The row-to-row distance was 3 feet, and plant to plant distance was about 2 feet. To examine all the parameters in each plot, five healthy plants were considered from each variety. The plant height of five selected healthy plants was measured from top to bottom with the help of a ruler manually and means data was calculated. Finally, the leaf area (cm^2) of selected plants was taken by measuring their leaf length and breadth. The average leaf size was computed by multiplying with a common factor of 0.644 derived by (Suggs *et al.*, 1960), with the formula:

$$\text{Leaf area} = \text{Leaf length} \times \text{leaf breath} \times 0.644$$

Determination of nicotine content

Nicotine was determined by the given formula suggested by Cundif and Markunas's (1964): V1×N×32.45×100 ÷ weight of the sample (Where, V1=Volume of titrant for non-acetylated aliquot, N=Normality of per Chloric Acid)

Identification of reducing sugar

Reducing sugar content was calculated with the following formula: % of Reducing sugars = 25 ×100× 0.05.

Statistical analysis

Statistical analyses were performed using ANOVA in the statistics program IBM SPSS Statistics for Windows, version 21.0 (IBM Corporation, Armonk, NY, USA).

Results and Discussion

Plant length

Various morphological characteristics of seven different PVH tobacco varieties have been analyzed. Plants length was recorded, at the time when the plant stopped further growth and fully matured at the end of the growing season after 117 days of transplantation (Figure 1). Plant height was measured from ground level to the apical inflorescence. For example, in the PVH-1600 variety, plant number-5 in replication-2 (P5R2) has the highest length (141 cm), while P2R1 has the lowest height of 116 cm (Table 1).

Figure 1: *Mature tobacco plants. Two plants of PVH-1600, which are 90 (A) and 117 days old (B). The 117 days old plant were used for leaves picking.*

Table 1: *Height data of fifteen selected plants from 3-replications of PVH-1600.*

PVH- 1600						
Replication 1		Replication 2		Replication 3		Mean
Plant	Length (cm)	Plant	Length (cm)	Plant	Length (cm)	
P1R1	136	P1 R2	136	P1 R3	135	129.33
P2R1	116	P2 R2	120	P2 R3	128	
P3 R1	123	P3 R2	140	P3 R3	126	
P4 R1	129	P4 R2	131	P4 R3	128	
P5 R1	126	P5 R2	141	P5 R3	117	
Average	126		133.6		126.8	

In all three replications, the variety is same (PVH-1600), but plant is different. Where P stands for plant, R for replication and both are followed by number 1,2,3… e.g. P1R1 represent plant-1 in replication 1 and so on. The highest length is 141 cm of plant number-5 in replication-2 (P5R2), while plant number P2R1 shows lowest plant height (116 cm). Mean value for PVH-1600 is 129.33cm.

The mean length data showed that the highest value was recorded for variety PVH-2329 (136.21), and thus displayed their superiority for this trait. However, the minimum plant height mean was reported in PVH2340 (122) (Table 7). Plant means height data of PVH-2329 is significant, which is closely followed by PVH-2324 with a height of 136 (Table 7; Supplementary Table S1-S6).

Number of leaves per plant (LPP)

The number of leaves per plant in tobacco is one of the major yield-contributing traits. Tobacco plants partaking in a greater number of leaves will produce more yields. The number of leaves was counted in fifteen selected plants from three replications in each variety, which was done one day before the first picking. All the seven varieties differed in their average number of leaves per plant (Table 7). The highest number of leaves (28) were produced by plant number-3 in replication-1 (P3R1) in PVH-2324 variety (Table 2), while the lowest number of leaves were 14 in plants P3R1, P2R3 in PVH-2340 (Supplementary Table S9) and in plant P2R2 in PVH-2324 varieties (Table 2). The highest mean number of leaves was observed in PVH-1600, which was 22 leaves per plant, while the lowest was observed for K-399 variety (18) as shown in (Table 7; Supplementary Tables S7-S12). The number of leaves showed a high significant (P> 0.000) difference among varieties.

Leaf area-related parameters

Leaf area is the major component for yield-enhancing in tobacco. Commercially, high prices are offered for long and broad leaves in the market. Highly significant mean-variance values (P>0.000) were observed regarding leaf area. The PVH-1600 has the highest leaf area (1241 cm^2), while PVH-2340 shows the lowest leaf area of 900 cm^2 (Table 7; Supplementary Table S13). These differences in leaf area might be due to the high uptake of nutrients.

Number of green leaves per five plants and their weight

The number of green leaves and their weight from selected plants were taken on picking day during 3-4 pickings in all varieties. The results indicated that the number of green leaves per five plants among various genotypes varied from 12-23 (Table 3, Supplementary Tables S14-S19). In the case of PVH-1600, which has the highest average number of green leaves (19) in replication^{-1} (Table 3). The PVH-1600 displayed the highest value of green leaves weight (29.3 Kg), while SPT-G-28 had the lowest (19.1 Kg) per plot (Tables 4, 7). Furthermore, PVH-1600 shows the highest mean (0.97) of green leaf weight (Table 3), whereas K-399 shows the smallest green leaf weight (0.45) (Table 7). Similarly, PVH-2275 shows the highest mean number of green leaves picked (23 leaves) per plot (Supplementary Tables S14).

Table 2: *Number of leaves in selected plants of PVH-2324 variety.*

PVH-2324-Number of Leaves per plant						
Replication 1		Replication 2		Replication 3		Mean
Plant	Leaves	Plant	Leaves	Plant	Leaves	
P1R1	19	P1 R2	19	P1 R3	18	19.23
P2R1	18	P2 R2	14	P2 R3	23	
P3 R1	28	P3 R2	24	P3 R3	19	
P4 R1	16	P4 R2	18	P4 R3	17	
P5 R1	21	P5 R2	16	P5 R3	16	
Average	20.4		18.2		18.6	

Plant is different but variety is same in all three replications. Where P represents plant, R represent replication which is followed by number 1 or 2 or 3. As P1R1 represent plant-1 in replication 1 of PVH-2324 and so on. Plant number P3R1 has the highest number of leaves (28) and plant P2R2 shows lowest number of leaves (14) in PVH-2324 variety. Mean value for PVH-2324 is 19.23.

Cured leaves weight

Cured leaves can easily determine the potential yield and their weight was determined after the curing process. The highest cured leaf weight was observed

Table 3: *Number of green leaves and weight from fifteen selected plants in PVH-1600 variety.*

PVH -1600 Number of green leaves and their weight									
Replication 1			Replication 2			Replication 3			
Picking number (K)	No. of green leaves per 5 plants	Green leaves weight (Kg)	Picking number (K)	No. of green leaves per 5 plants	Green leaves weight (Kg)	Picking number (K)	No. of green leaves per 5 plants	Green leaves weight (Kg)	Mean
K1R1	17	0.90	K1 R2	14	0.95	K1 R3	17	0.7	0.97
K2R1	34	1.65	K2 R2	32	2.15	K2 R3	32	1.45	
K3 R1	33	1.7	K3 R2	24	2.1	K3 R3	35	1.5	
K4 R1	13	0.45	K4 R2	18	1.1				
Ave	19	0.94		18	1.26		17	0.73	

In all three replications, variety is same but picking number is different. Where k represents picking, R represents Replication which is followed by number 1 or 2 or 3. As K1R1 represent picking-1 in replication 1 of PVH-1600 and so on. Picking number K2R2 has the highest number of green leaves weight (2.15 Kg) and K4R1 shows lowest green weight (0.45 Kg). Mean value for PVH-1600 is 0.97 Kg.

in the selected plants of PVH-1600 (4.60 Kg), while K-399 shows the lowest cured leaf weight (3.07 Kg) per plot (Table 7; Supplementary Table S26). The mean weight of cured leaves of selected plants of K-399 showed the highest value (0.227), while PVH-2324 showed the lowest (0.114) (Supplementary Tables S20-S25). PVH-2275 shows the highest average for the number of cured leaves (23 leaves) (Supplementary Table S20) and PVH-1600 shows the highest mean cured leaves weight (Table 5) and SPT-G-28 show the lowest cured leaves weight per plot as shown in (Supplementary Table S26). Statistical analysis shows significant values (P>0.05) among different hybrid varieties.

Table 4: *Mean values of green leave weight per plot.*

Varieties name	Weight (Kg) of green leaves/Plot
PVH-1600	29.3
PVH-2275	25.5
PVH-2340	21.8
PVH-2324	22.5
PVH-2329	24.9
SPT-G-28	19.1
K-399	25.8

PVH-1600 shows highest green leaves weight, while SPT-G-28 shows lowest green leaves weight mean.

Nicotine and reducing sugar contents

The presence of high nicotine contents negatively influences the distinctive physiological function of smokers, although very low content offers no pleasure to smokers. Our analysis showed a highly significant difference among varieties (P>0.01) in the variance of nicotine. A high amount of nicotine content was present in K-399 (2.91), while SPT-G-28 shows the lowest nicotine content (2.34) as shown in (Tables 6, 7). Reducing sugars is the most important chemical characteristic, which plays a vital role in the smoking quality and burning capacity of tobacco leaves. Statistical data regarding sugar content shows highly significant differences (P> 0.01). The PVH-2329 showed the highest mean value 15.83, which was nearly followed by PVH-2340 (15.77). However, SPT-G-28 was observed for the lowest (12.07) mean value for reducing sugar contents (Tables 6, 7).

Advances in tobacco research aim to find new uses. To compare tobacco hybrid plants, using molecular farming comprising new genes to produce new helpful products like vaccines, medicines and enzymes for industrial uses. Scientists are trying to promote the advantages of tobacco by developing new markets and customers for the new gene-enhanced tobacco (Huang *et al*., 2021). Previous investigation on the morpho-agronomic and qualitative performance of various FCV tobacco exotic hybrids on different varieties has been done with different experiments (Kamal *et al*., 2017). However, in the present study, we compare different tobacco hybrids that can lead to the finding of the most suitable genotype for a demanding region. All the agronomic parameters examined in the experiment were yield-contributing traits that affect the tobacco yield directly or indirectly. Comparatively most valuable varieties were PVH-1600 and PVH-2329. These varieties show significant differences in plant height, the mean number of leaves per plant, and leaf area. These are the parameters that may play a vital role in the total yield of the plant. PVH-1600 has the maximum mean number of leaves (22), leaf area

Table 5: *The number of cured leaves and their weight from fifteen selected plant in 3-replication of PVH-1600 variety.*

PVH-1600 Cured leaves weight of selected plants									
Replication 1			Replication 2			Replication 3			
Picking number	Number of leaves	Cured leaves weight (Kg)	Picking number	Number of leaves	Cured leaves weight (Kg)	Picking number	Number of leaves	Cured leaves weight (Kg)	Mean
K1R1	17	0.128	K1 R2	11	0.127	K1 R3	17	0.095	0.153
K2R1	34	0.253	K2 R2	32	0.315	K2 R3	32	0.223	
K3 R1	33	0.314	K3 R2	24	0.290	K3 R3	35	0.246	
K4R1	13	0.113	K4R2	18	0.200				
Average	19	0.161		17	0.186		17	0.112	

All the three replication have same variety but picking number is different. Where K represents picking, R represents Replication which is followed by number 1 or 2 or 3. As K1R1 represent picking-1 in replication 1 of PVH-1600 and so on. Picking number P2R2 has the highest number of cured leaves weight (0.315 Kg) nearly followed by K3R1 (0.314 Kg) and K1R3 shows lowest cured weight (0.095 Kg). Mean value for PVH-1600 is 0.153.

Table 6: *Percentage of mean values of nicotine and reducing sugar contents in all seven varieties.*

Hybrid varieties	Nicotine content (%)	Reducing sugar content (%)
PVH-1600	2.516	13.36
PVH-2275	2.69	14.59
PVH-2340	2.45	15.77
PVH-2324	2.67	15.09
PVH-2329	2.77	15.83
SPT-G-28	2.34	12.07
K-399	2.91	14.26

(1241 cm^2), green leaves (29.3 Kg), and cured leaves weights per plot (4.6 Kg). Furthermore, PVH-1600 also shows maximum mean values for green leaves (0.97 Kg) and cured leaves (0.227 Kg) weights respectively and PVH-2329 has the highest mean of 136.21 and PVH-2329 also has the maximum amount of reducing sugar (15.83 %). From the above facts, we can conclude that the morphological characteristics of the tobacco plant include plant height, leaf dimensions, green and cured leaves number, weight, Nicotine and Reducing sugar contents (%), and disease-resistant variety for the Mardan region. From the above result of all these field studies as well as laboratory studies variety, PVH-1600 and PVH-2329 were better than all other varieties concerning yield potential and morphological parameters.

Table 7: *Mean values for plant height (PH), number of leaves plant $^{-1}$ (LPP), leaf area (LA), green leaf weight/plot (GLWP), cured leaf weight/plot (CLWP), nicotine content (NIC), reducing sugars (RS), and the ratio of reducing sugars to nicotine (RS/NIC) of 10 flue-cured Virginia tobacco genotypes during 2004-05, Mardan.*

Tobacco genotype	Mean values of different parameters of seven varieties							
	PH	LPP	LA	GLWP	GLW	CLWP	NIC	RSC
PVH- 1600	129.3	22	1241	29.3	0.97	4.60	2.51	13.36
PVH2275	130.8	21	1056	25.5	0.85	4.02	2.69	14.59
PVH2340	122	19	900	21.8	0.75	3.62	2.45	15.77
PVH2324	136	19	975	22.5	0.75	3.37	2.67	15.09
PVH2329	136.2	21	1053	24.9	0.83	4.00	2.77	15.83
SPT-G 28	128.5	19	1034	19.1	0.46	3.07	2.34	12.07
K-399	132.5	18	1108	25.8	0.45	3.95	2.91	14.26

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Novelty Statement

The PVH-1600 and PVH-2329 showed the best performance in the agro-climatic conditions of Mardan out of seven exotic hybrid varieties for various parameters examined including high amount of nicotine and reducing sugar contents.

Supplementary Material

There is supplementary material associated with this article. Access the material online at: https://dx.doi.org/10.17582/journal.PJWSR/2023/29.4.221.228

Conflict of interest

The authors have declared no conflict of interest.

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