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Full Length Research

Hayman Analysis of the Inheritance of Growth and Ripening Rate in Elite Zimbabwean Virginia Tobacco (*Nicotiana tabacum* L.)

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Growth and ripening rates are important traits in flue-cured tobacco (*Nicotiana tabacum* L.) farming as they determine the field management required and indirectly influence the yield and quality of the cured leaf obtained from a variety. In this study growth rate was measured as the number of days from planting to 50% topping and while ripening rate was measured as the number of days from onset of reaping to 50% reaping. Understanding the nature of genes controlling growth and ripening rate in flue-cured tobacco is important as it allows breeders to predict with relatively high precision the outcome of breeding programmes. The F1 offspring of a 10 × 10 full Griffings' Diallel Method IV cross were evaluated in an alpha – lattice design experiment containing 100 entries in two replicates over a period of two years during the 2015/16and the 2016/17 summer seasons at Kutsaga Research Station under rain-fed conditions. Hayman analysis in the Statistical Package for the Sciences (SAS) 2014 Version was employed on the growth and ripening rate data which showed that the two traits exhibited partial dominance. The results indicate that it is possible to select for growth and ripening rate in flue cured tobacco breeding programmes.

Keywords: *Nicotiana tabacum* L.; growth rate; ripening rate; partial dominance; alpha lattice design; Hayman analysis

INTRODUCTION

Zimbabwe is one of the major growers of Virginia tobacco (*N. Tabacum* L.) in the world producing above 200 million Kgs of the cured leaf crop during peak years. The crop has become the major field cash crop and foreign currency earner for the Southern African country (ZimStats, 2016). Yield and quality are the major traits of interest in tobacco farming since these traits determine the ultimate price of the crop on the market. Early Virginia tobacco farming in Zimbabwe relied on variety introductions from the United States of America and Canada. These early varieties had the disadvantage that they lacked adaptation to local climatic conditions making it difficult for farmers to handle them both in the field and the grading sheds (Gildenhuys, 1952). Yields of these early varieties were very low and the quality was quite unacceptable 9 Gildenhuys, 1953). Early studies indicated that there was a relationship between yield and quality of the Virginia tobacco varieties and the growth and ripening rate of the same varieties. When the early breeding programs of Virginia tobacco were initiated in the country, growth and ripening rate of the developed varieties were taken into consideration. Varieties were classified either as fast or slow growing and fast or slow ripening. Early breeders like Raeber and Schweppenhauser reported that slow ripening varieties were associated with high cured leaf yields while fast growing varieties were associated with relatively low yields (Raeber and Schweppenhauser, 1967). Growth rate in Virginia tobacco was defined as the time it takes for a variety to develop to the standard topping height of eighteen leaves while ripening rate was defined as the rate at which leaves mature and become ready for plucking off from the plant stalk in readiness for curing.

On the other hand, the same early researchers observed that varieties that ripened fast gave very trashy tobacco that was often downgraded on the market fetching low prices. These varieties gave challenges to farmers on handling in the field as they would rot increasing the yield losses on the crop. It was observed that varieties that ripened at a rate of two leaves per week were ideal for the average farmer as most of the curing facilities could handle such varieties comfortably. Varieties that gave more than two ripe leaves per week were classified as fast ripening while those that gave less were labelled slow ripening. Whenever, varieties were developed in Zimbabwe, they would be classified based on whether they are slow or fast growing and ripening.

Although it was discovered that growth and ripening rate were important traits in Virginia tobacco farming, to our knowledge, no work was carried out by the early breeders in Zimbabwe to investigate the nature of inheritance and the genes that control these traits. Classification of the breeding material was rather based on mere observations without any recorded scientific experimentation. Understanding the nature of genes and their inheritance patterns is very important in crop improvement as it gives breeders insights on the likelihood of success in breeding for traits of interest (Nduwumremyi *et al.*, 2013; Bhor *et al*., 2014; Bindra, 2017). Such knowledge also allows the breeder to decide on the most effective mating designs to use if he/she was to quickly achieved the breeding goal (Shukla, 2017). This study was carried out to generate information about the nature of genes that control growth and ripening rate in Virginia tobacco germplasm and the nature of their inheritance.

MATERIALS AND METHODS

Making the Diallel cross

Griffings' Diallel Method IV was used to constitute the entries used in the study which included the reciprocals, selfs and the F1 hybrids. The crosses were made in the field during the 2014 -2015 cropping season at Kutsaga Research Station near Harare. The ten parents used to make the crosses are listed below on Table 1

Table 1: Diallel cross parental material

Entry code	Entry Name	Major characteristics
1	K326R1-1-28	Selection from the American line K326 known for its excellent quality. It is fast maturing
2	RWR3-2-12	Tall, multi-leafed line with moderate Alternaria resistance. Fast growing and ripening
3	ONCR3-4-6	A high quality leaf producing line with moderate root-knot nematode resistance
4	AW3R	Fast growing Alternaria leaf spot resistant line with big broad leaves
5	KM10	Giant line with many leaves. Fast growing and ripening. Highly susceptible t root-knot nematodes
6	XM26R1-1-26	A slow growing and ripening line giving predominantly lemon cures
7	XSR4-7-10	Slow growing and ripening. Gives predominantly lemon cures
8	BAZR3-6-18	Dark green line that gives predominantly orange to mahogany cures. It is slow growing.
9	XZR2-2-5	Slow growing and ripening. Gives predominantly lemon cures
10	KE1	A very old TRB line known for its thick few leaves and recommended for growing in hot environments. It gives predominantly deep orange cures.

Field experiment

A trial of 100 entries consisting of the F1 hybrids, reciprocals and selfs was set out in field as an Alpha lattice with two replicates and ten blocks for two consecutive cropping seasons starting from 2016 to 2017 at Kutsaga Research Station. Seedlings were raised using the float tray systemin July of every year of evaluation. Land for establishing the trials was ploughed early in April prior to the planting season and disced in September to create a fine tilth. Ridges of 60cm height were made and basal fertiliser at a rate of 500kh/ha (NPK: 6: 28: 23) applied. Planting was done in plots of 34 plants at an in-row plant spacing of 56 cm and inter-row spacing of 120cm. Water planting was done on the 25th of October each year with 5 litres of water in the planting hole and Fenvelerate applied at a rate of 30ml/ha to control cutworms. Weeding was done by hand using hoes and topdressing fertiliser applied at a rate of 100kg/ha four weeks after planting. Removal of the apical bud in a process called topping was done whenever plants attained 18 fully expanded leaves.

Data Collection and Analysis

Days to 50 % topping and reaping data was recorded and analysed using Statistical Analysis for the Sciences 2017 Version.

RESULTS AND DISCUSSION

Table 2: Hayman diallel mean squares for growth and ripening rate for individual and across seasons.

Item	Degrees of freedom	Season 1		Season 2		Across Seasons	
		Days to 50% Reaping	Days to 50 % Topping	Days to 50% Reaping	Days to 50 % Topping	Days to 50% Reaping	Days to 50 % Topping
A	9	64.07*	26.97	369.27***	67.00	136.30	30.82
b1	1	30.68	9.26	3.47	0.14	13.69	0.42
b2	9	7.91	5.89	6.91	6.74	4.86	4.11
b3	35	11.25	7.71	12.07*	9.85*	5.03	5.01
B	45	11.02	7.38	10.85	9.02*	5.19	4.73
C	9	15.1	15.89	369.87***	33.03	91.90	7.01
D	36	18.00***	5.26	8.37	9.67	7.69	3.48
T	99	18.75	9.16	75.17	16.71	25.90	6.86
Block	1	182.41	24.68	2.21	7707.85	29209.45	7849.54
Block.a	9	12.73	13.55	9.73	34.37	80.37	19.12
Block.b1	1	63.85	0.22	17.80	1.72	3.38	5.74
Block.b2	9	10.55	14.08	7.13	4.16	2.55	2.38
Block.b3	35	13.19	9.30	6.39	5.53	6.63	3.75
Block.b	45	13.79	10.05	6.79	5.18	5.74	3.52
Block.c	9	10.82	8.69	6.35	20.77	100.58	17.29
Block.d	36	6.18	8.63	5.00	8.04	5.50	3.98
Block.t	99	10.66	9.73	6.37	10.29	21.06	6.36

For both the traits measured, there is inconsistent response from seasonone to seasontwo and across the years. Hayman's diallel analysis shows that additive gene action was significant for days to 50% reaping was significant for both seasonone and seasontwo but not significant for across year analysis (Table 2). Additive gene action for dark flue-cured leaf colour was also significant during year one and on the across year analysis but not significant on seasontwo analysis. There was some dominance gene action, though, peculiar to some crosses as shown by significant b_3 during seasontwo for days to 50% reaping and days to 50% topping. There were some additive maternal effects for days to 50% reaping during seasontwo only and significant maternal interaction effects during season one

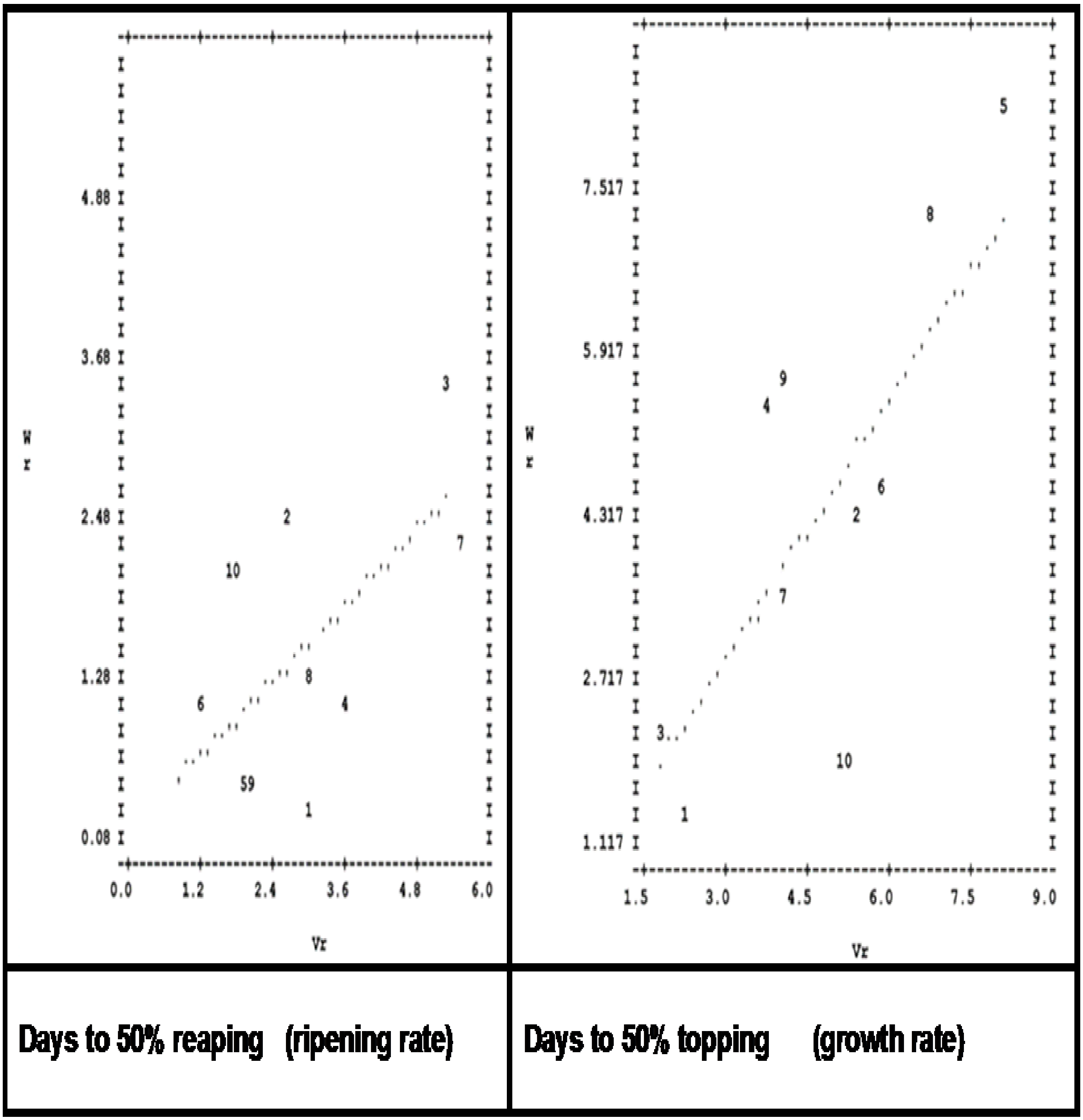

Figure 1: Hayman's graphical display of days to 50% reaping, and days to 50% topping for the 2015-16 season.

The graphs suggest partial dominance gene action on all the traits investigated since the regression line cuts the Wr line above the origin (Figure1). Parents 6 (XM26R1-1-26), 5 (K M10), 9 (XZR2-2-5) and 1 (K326R-1-1-28) have more dominant genes for days to 50% topping while parent 2 (RWR3-2-12) has more of the recessive genes for the same trait. For trait days to 50 % reaping (ripening rate) parent 1 (K326R-1-1-28), 3 (ONCR3-4-6) and 10 (K E1) have relatively more dominant genes. Parents 4 (AW3R), 1 (K326R-1-1-28), and 7 (XSR4-7-10) also have the highest number of dominant gents for producing dark flue-cured leaf colour.

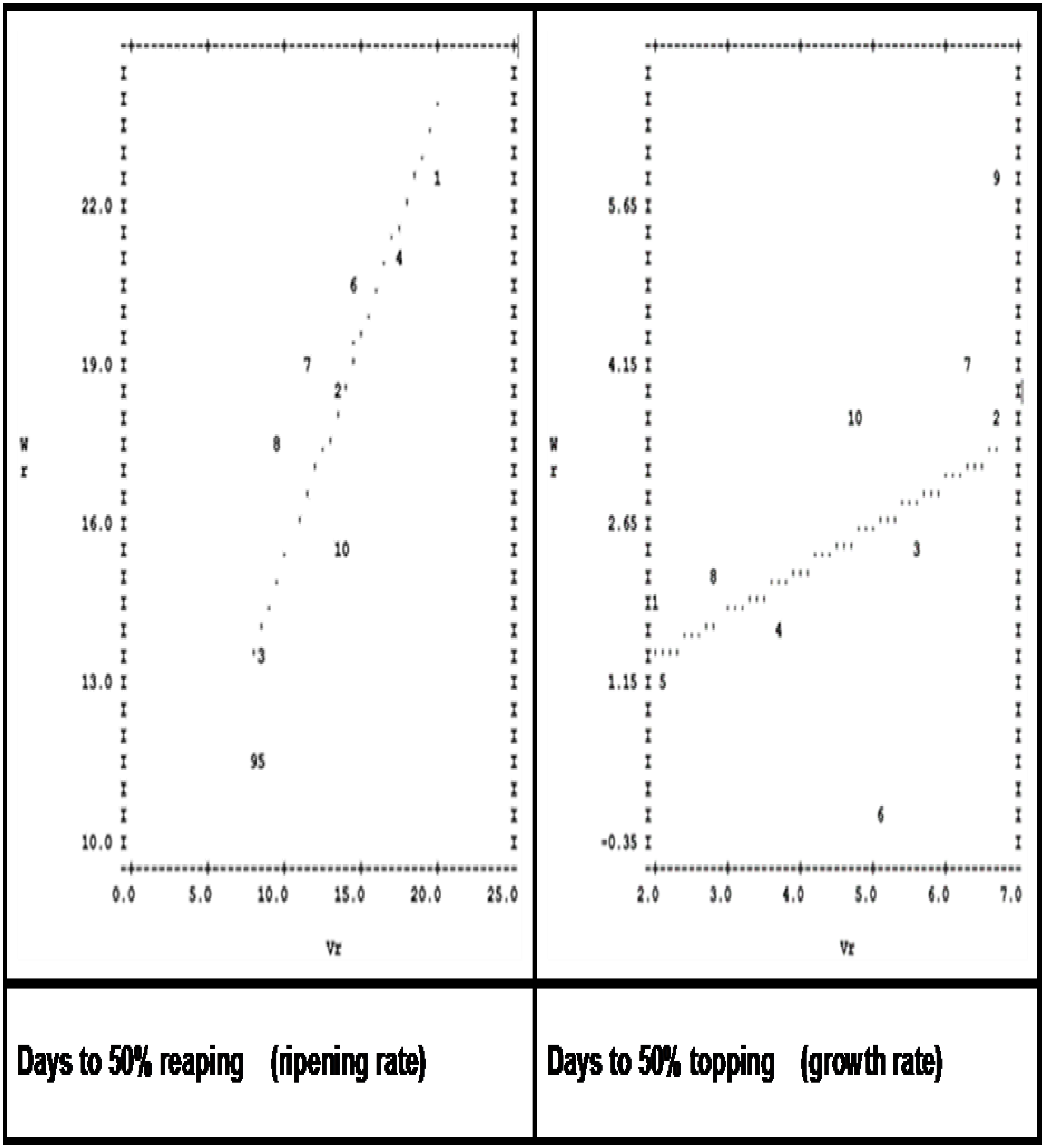

Figure 2: Hayman's graphical display of days to 50% reaping, and days to 50% topping for the 2016-17 season.

Since the regression line cuts Wr line above the origin, the output suggests partial dominance for all the traits under investigation during the second season of study, that is, season 2016-17 (Figure 2). Parent 2 (RWR3-2-12) has more dominant genes for the trait dark flue-cured leaf colour while parents 6 (XM26R1-1-26) and 5 (K M10) have more dominant genes for days to 50% topping. Parents 5 (K M10), 9 (XZR2-2-5) and 3 (ONCR3-4-6)have more dominant genes for the trait days to 50% reaping.

Combined season Hayman graphical gene action display for the traits growth rate and ripening rate.

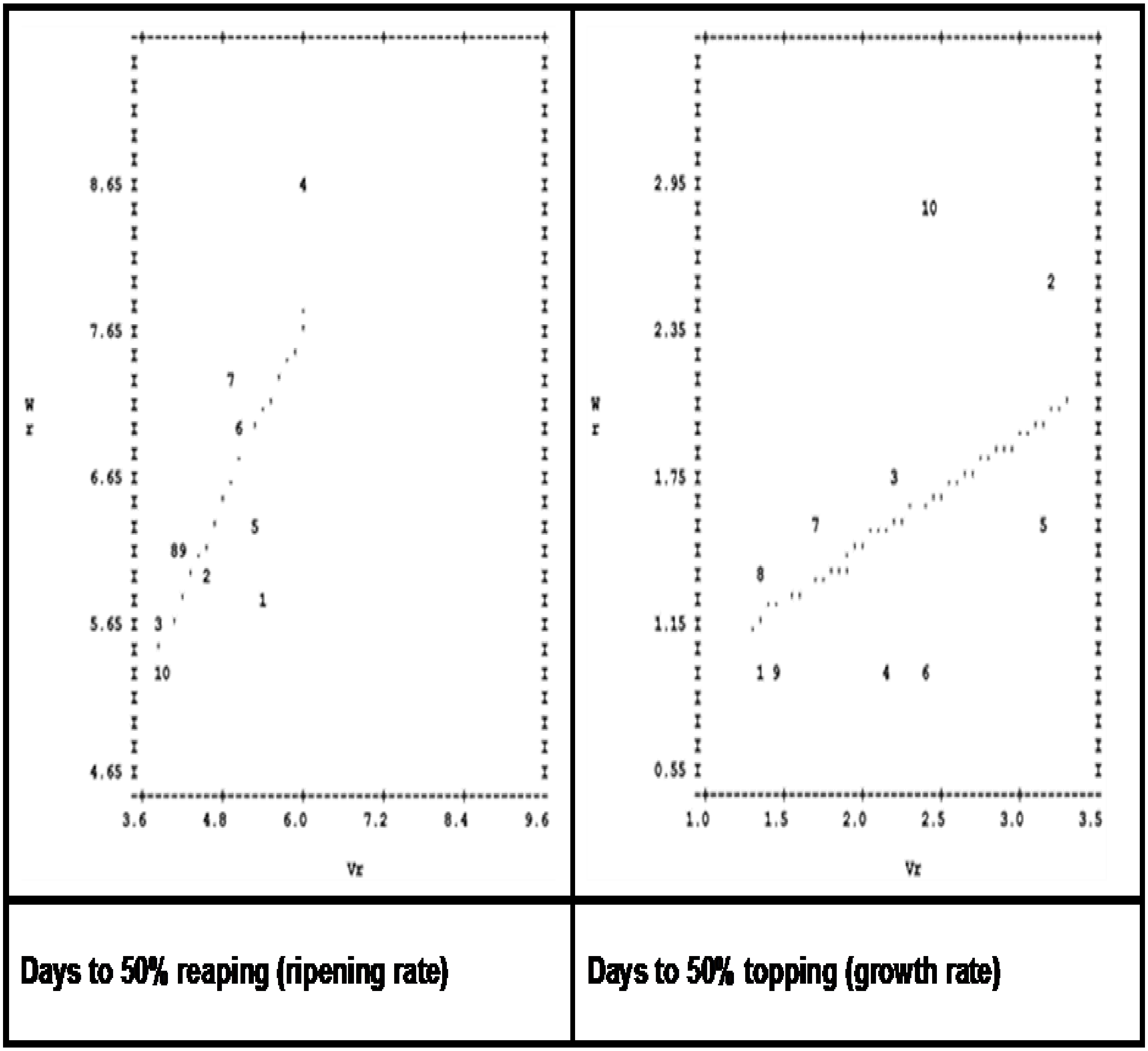

Figure 3: Combined Hayman's graphical display for days to 50% reaping (ripening rate) and days to 50% topping (growth rate) across two seasons

Hayman's graphical output suggests partial dominance for the traits days to 50% reaping, days to 50% topping and dark flue-cured leaf colour production (Figure 3). This is because the regression line cuts Wr line above the origin. Parents 1 (K326R-1-1-28) and 9 (XZR2-2-5) have the highest proportion of dominant genes for genes days to 50 % topping while parents 3 (ONCR-3-4-6) and 10 (KE 1) have the highest number of dominant genes for the trait days to 50% reaping. Parent 4 (AW3R) has highest number of genes favouring producing dark flue cured tobacco leaves.

CONCLUSION

The traits days to 50% topping and days to 50% reaping exhibit partial dominance in their inheritance. This shows that it is possible to select for the traits with success in tobacco improvement programmes. Lines 1(K326R-1-1-28) and 9 (XZR2-2-5) exhibited the highest level of dominance for the trait days to 50 % topping while the lines 3 (ONCR3-4-6) and 10 (KE 1) were relatively more dominant for the trait days to 50% ripening.

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