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Stability and Adaptation of New Tobacco Varieties to Three Growing Areas under Rain Fed Conditions in Zimbabwe

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ABSTRACT

Background: Variety development is a continuous process that caters for the ever changing farmer crop growing conditions. Changing climatic conditions, soil fertility conditions, crop disease and pest regimes as well as farmer agronomic practices require that new varieties adapted to new practices be availed to growers so that they continue to get high yields. Initial variety development processes are carried out by the breeder, usually on station and usually involves aggregation of traits of interest into a genotype with little or no information about the response of the genotype to different farmer cropping situations. However, before the varieties can be recommended to growers, they need to be evaluated in multi-environment trials (MET) in order to identify varieties with broad adaptation for general recommendation and those with specific adaptation for targeted environment production.

Methods: In order to evaluate the adaptation and stability of newly developed tobacco varieties to three growing locations in Zimbabwe, seven varieties were evaluated in a randomised complete block design with three replicates at Kutsaga Research Station near Harare, Trelawney and Tengwe over three seasons ranging from 2013 to 2015.

Result: The study results showed significant differences among the varieties and locations tested for saleable yield ($P<0.05$). Of all the varieties tested, T76 was the most stable showing consistently high performance across the seasons and locations tested followed by T75. However, ETH03 was the least stable variety of them all. Unlike what is currently believed in the tobacco industry in Zimbabwe, the variety K RK26 is no longer the most broadly adapted. Based on the study results, the varieties, T76, T75 and ETH06 are stable and, therefore, recommended for growing across the whole of the tobacco farming belt in Zimbabwe.

Key words: Adaptation, Environment, Genotype × Environment interaction, Multi-environment trials (METs), Stability, Variety.

INTRODUCTION

The constantly changing crop growing conditions necessitate the continuous development of crop varieties that guarantee farmers decent yields (Allard, 1999; Singh, 2006). Such changes which have come in the form of unpredictable rainfall patterns, extreme temperatures (Mba *et al*., 2012) and loss of soil fertility render previously well established varieties unfit to be grown competitively. The solution to such a problem is development of new varieties that fit the prevailing management and climatic conditions (Lane and Jarvis, 2007). New varieties require testing in growing environments where the crop is mostly grown to study their performance and suitability in specific growing conditions (Farshadfar *et al*., 2013). Variety testing in multi-location environments is done for at least two seasons in order to establish their stability and adaptation to wide growing conditions. In Zimbabwe, the tobacco growing region is divided into three namely the fast, the slow and the medium growing regions. Before new varieties are officially released for cultivation by farmers, they are tested in each of these areas. The objective of the testing would be to identify the best performing varieties in each of the growing environments for farmer recommendations. Environments differ in their ability to support different genotypes and environments it is refereed to edaphic, climatic and management conditions done by the farmer depending on the growing environment in which the farmer produces a crop (Mohamed, 2013, Muniswamy *et al*., 2017). Years also differ in their ability to support a crop, the reason why they are tested as rain fed in multi-location trials (Gauch, 1988). So year and location combinations are referred to as the environment in this study. The objective of the study was to identify varieties which do best in each of the tested environments and also those which have had adaptation. This could make it easy for variety agronomists to recommend cultivars for specific growing environments.

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MATERIALS AND METHODS

Agronomic management of the trial

Seedlings for the experiment were raised using the conventional tobacco seedbed approach at all the sites each year. The six new tobacco varieties and a control were grown at three locations, Kutsaga Research Station near Harare, Firhill Farm in Trelawney and Oldonyo Farm in Tengwe

(Karoi). Kutsaga Research Station is in the slow, Trelawney in the medium while, Tengwe is in the fast tobacco growing area. The experiment ran for three seasons from 2012-13 to 2014-15. At each location the experiment was set as a randomised complete block design (RCBD) with three replicates. Plants were planted on raised ridges. Each plot consisted of two rows spaced at 120 cm between rows and plants spaced at 56 cm within rows. Planting was done during the third week of October each year using the water planting method which involves planting a seedling in a hole filled with 5 litres of water. Basal fertiliser (N:P:K - 6:23:20) was applied in the ridge before planting and Ammonium Nitrate (AN) applied at a rate of 8 g per planting station 4 weeks after planting (WAP). Topping was done at 8 WAP while reaping started at 8 weeks and continued until all the 18 leaves were taken off the land for curing and graded using the TIMB classification guidelines of 1994 to separate saleable leaf from unsaleable leaf.

Data analysis

General across site analysis of variance was carried out on saleable yield in Genstat Version 18 and the GGE biplot in the same software was used to show stable varieties across the sites and seasons.

RESULTS AND DISCUSSION

Combined analysis of variance (ANOVA) for saleable yield

The combined analysis of variance for the seven varieties in nine location-year environments showed that all the main effects in the study were highly significantly different ($P < 0.05$) among each other (Table 1). The genotype main effects showed significant differences indicating differences in yield performance among the evaluated genotypes in different environments across years in which they were environments. Such differences are expected since each genotype is a collection of a set of genes that respond to the environments where they are subjected differently. The environment main effect also indicated significant differences ($P< 0.05$) showing that there were differences in the ability to support genotypes among nine environments evaluated. The main objective of conducting multi-environment trials (MET) is to generate information that identifies varieties that suit different locations and unique or specific cropping situations (Yadah *et al*., 2014; Gauch and Zobel, 1997). Such information helps agronomists recommend varieties that do best in specific environments. It also helps plant breeders rank varieties based on their performance in different growing conditions and be able to choose the best varieties to for eventual release to farmers for cultivation (Zobel *et al*., 1988). In MET analysis, it is common practice to treat environments as location - year combinations and go on to identify the best location year combination environment. This is because the across site analysis that considers the environment alone would have shown non-significant genotype by environment interactions. Location - year combinations are then treated as environments and varieties are identified that suit the best location-year combination environment. It is true that location-year combinations are different in scientific terms but the limitation with this approach is that it assumes that season characteristics are fixed and can be repeated, which is not the case. Unless the analysis is based on covariance using weather data, such recommendations may not useful to either the breeder or the agronomists or farmer since it is very difficult to repeat a year or season that is exactly like what has been experienced as well as its effects on each crop growing enevirironment in the future and combine it with variety that is always fixed. For that reason, this paper does not identify mega-environments and identify “which – won – where” for the reason that the results of this study targets mainly the agronomists who recommend varieties to growers. Stability is what is important under this scenario and that is what is discussed mainly.

Variety performance across environments

Table 1 ANOVA showed that genotype main effects were significantly different ($p < 0.05$). Although the genotypes gave an above average performance in terms of cured leaf yield, there were some varieties that outperformed others across the locations and seasons evaluated. The genotype T76 outperformed all the other genotypes across all the years and seasons tested (Table 2). At all sites T75 comes second followed by T74 and ETH03 is always coming last. The consistence of position among the varieties in terms of rankings across all the locations tested show that there are no crossover interactions for saleable yield between the locations and the genotypes.

Mean environment performance across years

The environment in which a genotype is grown affects the performance of that genotype. Some genotypes interact positively with environments while others interact negatively

Table 1: Combined analysis of variance for saleable yield.

Source of variation	D.F.	S.S.	M.S.	V. R.	F. Prob.
Environment	8	93842252	11730282	38.56	<.001
Residual	18	5475607	304200	1.41	
ENV.BLK.*Units* stratum					
Genotype	6	5184535	864089	4.01	0.001
Env * genotype	48	20338049	423709	1.97	0.002
Residual	108	23283765	215590		
Total	188	148124208			

Table 2: Variety yield performance across locations and years.

Site	Treatment	Year			
		2013	2014	2015	Variety Mean
Kutsaga	ETH03	2398	1953	2003	2118
	ETH04	2540	2340	2151	2344
	ETH06	2490	2733	2267	2497
	KRK26	3188	1947	1913	2349
	T74	2249	1646	2151	2015
	T75	2832	2682	2437	2650
	T76	2818	2944	2389	2773
Tengwe	ETH03	2459	2394	2764	2539
	ETH04	1597	2104	3443	2381
	ETH06	1913	1719	2930	2188
	KRK26	1677	2223	2573	2158
	T74	2142	2201	2260	2201
	T75	2020	2575	3027	2541
	T76	3129	2019	3195	2781
Trelawney	ETH03	1952	4219	2665	2945
	ETH04	1899	3625	3093	2872
	ETH06	1679	4772	2803	3085
	KRK26	2027	4012	2478	2839
	T74	2089	5537	2161	3262
	T75	2182	4498	2773	3151
	T76	2541	4508	2952	3333

Table 3: Location average yield performance across years.

Site	2013	2014	2015	Mean
Kutsaga	2645	2321	2187	2384[a]
Trelawney	2053	4453	2703	3070[b]
Tengwe	2134	2176	2885	2398[ac]

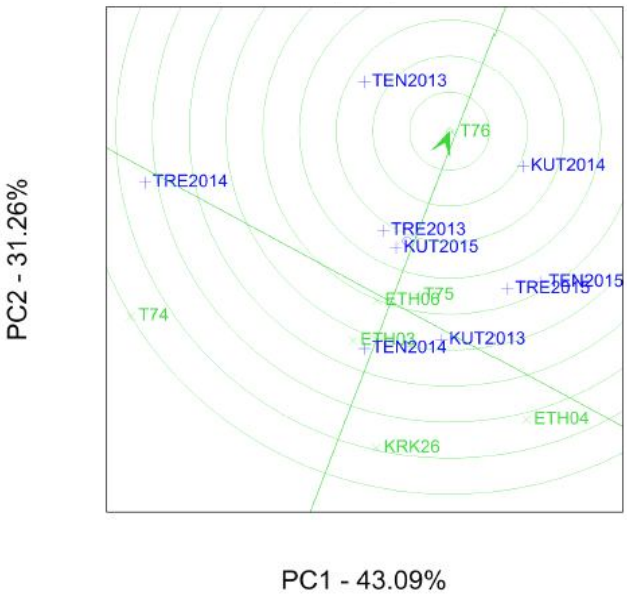


Fig 1: G GE biplot showing the relative stability of the varieties across the test environments.

resulting in a poor performance of the variety. By environment it is referred to the whole set of growing conditions that may affect the growth and development of a genotype. This covers aspects like soil properties, weather pattern, pest and disease regime as well as other farmer practices that contribute towards the success or failure in performance of a variety. As shown on Table 3, environments differed in their ability to support the genotypes evaluated. Trelawney gave the highest performance of 3070kg/ha followed by Tengwe with 2398 kg/ha and lastly came Kutsaga with 2384 kg/ha. Trelawney gave the highest yields because of consistent and good field management by the farmer. Tengwe usually gives high yields (TRB Annual Report, 2012) but mid season droughts affected the location consecutively resulting in low yields. Kutsaga gets low yields mainly because of variable field crop management from one season to another and too much cured leaf handling losses.

Yield stability of varieties across environments

The combination biplot shown on Fig 1 show the presence of genotype × environment interaction in flue cured tobacco as was reported by Shava *et al.* (2019) and the relative stability of all the varieties tested in all the environments. The biplot is typified concentric rings and the variety that occupies the closest position to the centre of the set of rings is the most stable variety. From the plot, T76 is the most stable varieties among all of them evaluated. T76 is a variety that has high resistance to alternaria leaf spot as well as angular leaf spot race 1. It has a high capacity to give leaves that have a high filling value. Because T76 has one of its parent's bred for wide cultivation in the early 60's (TRB Annual Report, 1964) it can be presumed that its broad adaptation is as a result of the contribution of this line AW3R. Going outwards, it can be seen that T75 and ETH06 follow. From the results, T74 is the least stable variety of them all followed by K RK26. The lack of stability of the variety T74 is understandable since it is a late maturing variety developed mainly for the fast growing areas where high temperatures favour its quick growth. The variety that has behaved unusually is K RK26 which is often characterised as have broad adaptation yet the results show otherwise.

CONCLUSION

From the results of this study, it can be concluded that locations, Kutsaga, Trelawney and Tengwe differ in their ability to support tobacco genotypes. Trelawney is the best environment for tobacco farming and Kutsaga and Tengwe are comparable in their ability to support tobacco farming. There is indeed significant genotype by environment interactions for saleable yield in tobacco when the environment refers to location-year combinations. From the study, T76 is the most stable variety and T74 is the least stable in terms of saleable yield. Unlike what is believed in the tobacco industry, K RK26 is not the most stable variety currently on the market. The most stable variety is T76 followed by T75 and ETH06.

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