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Genetic Variations of Two Elite Tomato Varieties Yield and its Parameters in Nangarhar, Afghanistan

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ABSTRACT

Background: Tomato is considered as one of the most import crop in food industry due to its great health benefits in all over the world; especially in Afghanistan as it has been significant rule on boosting of balance of trade. This Study indicated the field experiment was conducted to evaluate the potential productivity of two elite tomato varieties, CXD_222 and Roma_VF, in Nangarhar, Afghanistan.

Materials and Methods: The experiment was conducted in a Randomized Complete Block Design (RCBD) with four replications in 2018 and 2019. Yield and yield parameters were measured at the red-ripe maturity stage.

Findings: The results revealed that CXD_222 produced significantly higher yield than Roma VF. Branch number were not significantly different; however, CXD_222 had significantly higher number of fruits per plants than Roma_VF. CXD_222 produced 3.72 and 3.88 kg tomato in 2018 and 2019, respectively whereas the yield was 2.5 and 2.63 kg in Roma_VF for the respective years. There was a strong correlation between fruit number per plant and fruit yield in both varieties which suggests that higher productivity in CXD_222 is solely due its capacity of producing higher number of fruits.

Conclusion: This study indicates that CXD_222 is a viable alternative to the long-used Roma_VF tomato variety.

Keywords: Tomato Yield; CXD_222; Roma_VF; Genetic Variation; Nangarhar

INTRODUCTION

Cultivated tomato (Solanum Lycopersicum L.) belongs to the Solanaceae family and is classified in the Lycopersicon section of Solanum. Tomato is one of the important globally consumed crop. More than 141.4 x 10^6 tons of tomato was harvested worldwide in 2009 (Olander et al., 2013). It is characterized to be available year-round and has significant health benefits. Tomato was first domesticated by the Native Americans and there is a possibility that the origin of tomato is Mexico. No one really knows how the current big fruit size occurred through evolution because its domestication happened in pre-historic times. It appears; however, that the current big size of the tomato is due to efforts of the Native Americans who were looking for mutated plants with big fruits.

Several factors including variety, sunlight, temperature, pollinators, water supply, nutrients and others determine the yield and health benefits of tomato (Dorais, 2005). In 2004, It was reported that tomato was cultivated on about 7,940 ha land and produced up to 85000 tons harvestable yield in Afghanistan (Abbas et al., 2012). The Food and Agriculture Organization (FAO) stated that tomato accounted up to 16% of horticulture crops in Afghanistan (Masini & Giordani, 2016). For having large quantity of water (Abraham et al., 2011), this plant is very sensitive to several factors and can easily perish (Nasrin et al., 2008). Moreover, poor cultural practices and post-harvest management can cause great losses (Rahman & Hossain, 2005).

Although over 80 percent of population is engaged in agriculture, Afghanistan is not self-sufficient in terms of tomato production; therefore, it relies on neighboring countries especially Pakistan to meet the tomato demand of the people. This is largely due to the long-lasting civil war that has destroyed agricultural infrastructures and research centers (Gulab et. al., 2020).

A number of factors challenge the production of tomato. The biggest challenge comes from the lack of infrastructures and research (Gulab et al., 2020). Currently, farmers rely on the seeds and seedling that are available in market or they use the seed of crops they harvest in previous season. Poor seed and seedling quality thus pose another challenge toward greater yield production in the country. To overcome this challenge, a study was required to test the productivity of recently imported tomato varieties. The Campbell varieties were reported to be the highest yielding genotypes in a study conducted in Balkh, Afghanistan (Mark, 2006) whereas the Roma_VF which is the widely grown variety of tomato had poor yield performance. The yield performance of these varieties, however, has not been checked in Nangarhar, Afghanistan which is famous for vegetable gardening. The study to assess the genetic yield potential of CXD_222 and Roma_VF tomato varieties in a stress-free environment in Nangarhar, Afghanistan and as study estimates the effect of variables as well compare the two varieties.

MATERIALS AND METHODS

Planting materials

Seeds were acquired from a trusted seed supplier in the market. Small seeding trays were filled with 2/3 sandy loam soil and 1/3 compost. The seeds were sown in these trays in spring 2018 and 2019. For a faster growth, we dissolved 20 g of urea in water and applied in a square meter. The trays were stored in a tunnel shaped plastic green house and were irrigated every other day. We used the Random Complete Block Design with four replications where each plot was 3 X 3 m. After the unfolding of 3rd true leaf (5 weeks after sowing), the seedlings were transplanted to field with already prepared furrows. The soil type was clay loam in the field with

a PH of 7.5. The centers of the furrows were 50 cm apart and each row was roughly 15 cm high. Planting space between seedlings in a row was 50 cm. An 80:60 $kgha^{-1}$ratio of Urea and DAP was applied to avoid nutrient problems. Total DAP and half of Urea was applied during transplanting and the remaining half of the urea was applied 30 days after transplanting. The seedlings were pruned slightly in order to avoid bushy plants and fruit setting close to the ground. We irrigated the field every week. Pesticides were used as necessary.

Yield Measurement

A two square meter area in the center of each plot was fenced with a string. This area then divided by two equal sections in order to increase the sampling size and reduce the variability. Border plants were not used in this study because they can be affected by several factors. Tomato were collected as soon as they reached the red-ripe maturity stage. Total yield per plant was the sum of all the fruits we harvested from the same plant. Every time the tomato was harvested, they were weighed and recorded. We measured the weight of four tomatoes in each harvested batch. The number of fruit bearing branches were also recorded after the fruit was harvested. The average value of these parameters per each square meter was used as the final observation for statistical procedures.

Statistical Analysis

We used Two-way analysis of variance (ANOVA), Tukey's test of multiple comparison (Tukey HSD), and Pearson's correlations test to validate the data. Two-way ANOVA was used between the different varieties, sowing years, and variety and sowing year interaction. We used Pandas, Numpy, Scipy and Pingouin libraries in python and Agricolae package (Mendiburu, 2015) in R for statistical procedures.

RESULTS

We observed significant difference in the yield performance of these two varieties; CXD_222 produced 3.72 kg and Roma_VF produced 2.5 kg fruit in square meter area in 2018, respectively. A slight increase in fruit yield was observed in both varieties in 2019 where CXD_222 had a fruit yield of 3.88 kg and Roma_VF produced 2.63 kg tomato. There was significant difference in yield per land area and per plant between the two varieties **(Fig. 1).**

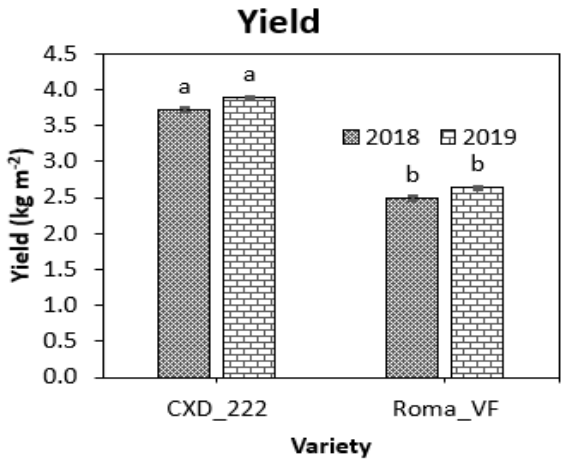

Fig.1. Average tomato yield in two elite tomato varieties. Bar show the mean of 16 observations. Standard error of sample is used to indicate the dispersion of the data from the mean. Letter on the top of each bar indicate level of significance.

. In 2018, CXD_222 produced significantly heavier fruits than Roma_VF whereas the difference was not significant between the two varieties in 2019. In 2018, the average fruit size of CXD_222 and Roma_VF was 98.31g and 97.54 g, respectively. A steep drop in the fruit size of CXD_222 was observed in 2019 whereas the fruit size of Roma_VF increase nearly two-fold. The average fruit size for CXD_222 and Roma_VF was 97.54 and 97.73 g, respectively. Although the Roma_VF produced heavier tomato in 2019, there was no significant difference between them **(Fig. 2).**

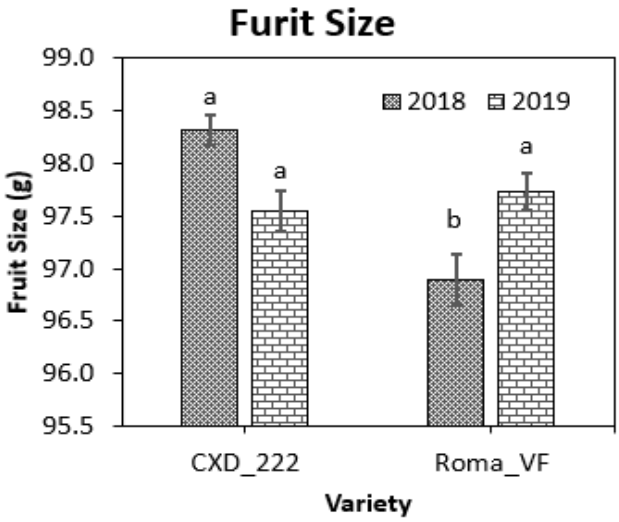

Fig. 2. Average fruit size is in gram. Bars show the mean of 16 observations. Standard error of sample is used to indicate the dispersion of the data. Letter on the top of each bar indicate level of significance between the varieties.

The fruit number per plant was observed and analyzed to be significantly higher in CXD_222 variety than Roma_VF in both growing years. An average, CXD_222 produced 9.47 and 9.95 tomato per plant in 2018 and 2019, respectively. On the contrary, Roma_VF had an average number of 6.45 and 6.74 tomato per plant. Comparing 2018, the fruit number was higher, but not significant for both varieties in 2019 **(Fig 3).**

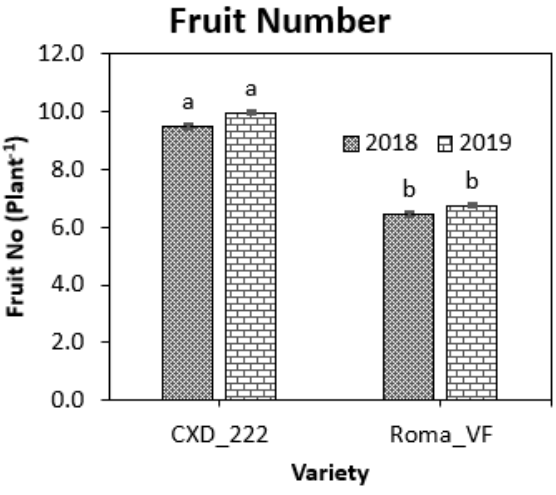

Fig.3. Average fruit number per each plant. Bars show the mean of 16 observations. Standard error of sample is used to indicate the dispersion of the data. Letter on the top of each bar indicate level of significance.

The following table summarizes some of the key yield parameters and statistical significance in both varieties. As can be seen, yield in square meter and yield per each plant was significantly higher in CXD_222 than Roma_VF in both years. The fruit size was higher in CXD_222 in 2018, but the difference was negligible in 2019. There was no significant difference in branch number between the two varieties. Fruit number per plant and fruit number per branch; however, remained significantly higher in CXD_222 than Roma_VF. Yield of fruit number per branch and fruit number per plant was higher in 2019 than 2018. The varietal and yearly interaction was seen in fruit size and branch number per plant, but it was not significant in other yield parameters.

Table 1. Analysis of variance on yield, fruit size, fruit number, branch number and fruit number per branch

Factor			Yield m^{-2}	Yield (g $plant^{-1}$)	Fruit Size (g)	Fruit No ($plant^{-1}$)	Branch NO ($plant^{-1}$)	Fruit No ($Branch^{-1}$)
Mean	Year (Y)	2018	3.11	778.44	97.60	7.96	2.91	2.74
		2019	3.26	815.01	97.63	8.34	2.90	2.87
	Variety (V)	CXD_222	3.80	951.57	97.93	9.71	2.92	3.33
		Roma_VF	2.56	641.91	97.31	6.59	2.89	2.28
	ANOVA	V	0.000***	0.000***	0.001**	0.000***	0.52*	0.000***
		Y	0.000***	0.000***	0.84^{ns}	0.000***	0.73^{ns}	0.003**
		V x Y	0.36^{ns}	0.43^{ns}	0.000***	0.16^{ns}	0.025*	0.35^{ns}

***= $\rho < 0.000$, **$\rho = 0.01$, * = $\rho < 0.05$, n.s.= not significant.

As **Fig. 4** and **Table 2** showed, the yield enhancement in both varieties was due to higher fruit set. Correlation matrix in a pooled data also showed a strong correlation between fruit size and yield but our analysis (data not shown) revealed that it was because of the higher fruit size of Roma_VF. This means that CXD_222 produced higher number of fruits in a plant. Therefore, it had yield superiority over Roma_VF. The fruit number was Relatively smaller in 2018 and it was due to the bigger fruit size. In fact, the cross-species fruit size had contribution to the yield enhancement in 2018, but the difference was negligible in 2019. Roma_VF produced smaller and fewer fruits in 2018 which could be due to continues hot weather that might have stressed the plant. With the ideal conditions of 2019; however, the fruit size was higher than CXD_222 although not significant. This indicates that if external factors do not play their role, the genetic yield potential in CXD_222 is solely to higher fruit setting rate (Fruit Number).

The final outcome of ANNOVA analysis of these variables consist, the fruit number outcome. There has been high association between the fruit size, fruit number and branch number. Furthermore, fruit number p value is 0.003, there is significant difference between other variables. Statistical test will be 0.003<0.005. Null hypothesis is rejected but there is significant difference between the other variables.

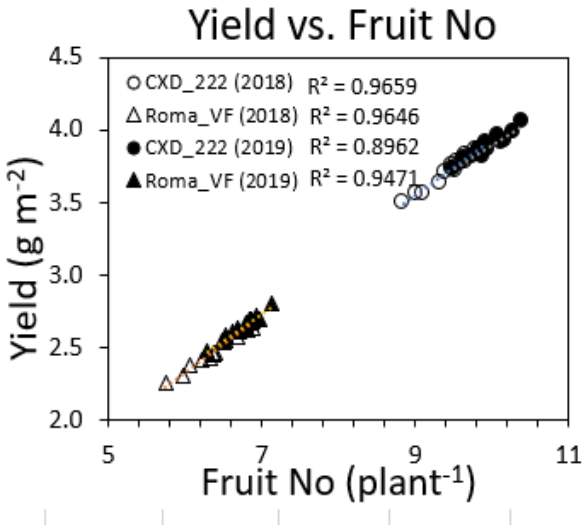

Fig.4.correlation between fruit No and Yield. Each correlation is drawn between 16 observations.

Table 2. Correlation between yield parameters. Correlation coefficients is drawn from an n=64 sample size. Cross-species and cross-year difference is not taken into consideration because the trend for yield remained the same for both years.

Correlation in Stacked Data

	Yield	Fruit Size	Fruit No	Branch No
Fruit Size	0.34**			
Fruit No	0.99***	0.30*		
Branch No	0.049	0.02	0.049	
Fruit branch^{-1}	0.97***	0.30*	0.97***	-0.16

*** = ρ < 0.000, ** = ρ < 0.001, * = ρ < 0.05

DISCUSSION

Variations in the genetic yield potential of tomato, with or without treatments, have been studied in several studies. Although great discrepancies exist in their results, recent release tomato varieties usually performed better than the old varieties (Amundson et. al., 2012; Gulab et al., 2020; Helyes et al., 2012; Tanksley, 2004). This is largely due to the selection and breeding of tomato genome for hunting highly productive genotypes (Tanksley, 2004). We conducted a study about two tomato varieties that are currently used in Afghanistan and around the world. The results revealed that CXD_222 which is one of the elite genotype from the Campbell variety produced significantly higher yield and was consistent in our two years long research. The average yield potential of CXD_222 for 2018 and 2019 was 38.0 metric tons in a ha. On the contrary, the Roma_VF produced 25.67 metric tons in a ha. Our study is consistent with the finding of Mark, (2006) but the magnitude at which

we produced tomato was drastically higher. He reported 27.7 tons of yield in a Hectare (ha) for the CXD_222 and 18.8 tons for Roma_VF which is indeed not as good as in our findings. This difference could be related to the better cultural practices and management techniques we applied in our research.

ANOVA test in Table 1 showed the interaction of year and variety in fruit size as well as branch number. This means that the fruit size and branch number per plant are not stable factors and are subjected to changes in different seasons. It has been well established in nearly all crops that a higher number of fruit production is usually associated with smaller fruit size and thus the smaller fruit size in CXD_222 in 2019 was compensated with higher number of fruit setting rate. It appears that the year and variety interaction was due to the hot weather conditions in 2018 that has affected Roma_VF. A similar strange correlation existed between the fruit size and Fruit number and fruit number in branch, but this was only significant when the data of both varieties for both years were combined. For each genotypes, however, the correlation was only significant in 2019 for Roma_VF. Since there was no consistency between both years, this correlation can be safely ignored.

To the best of our knowledge, this is the first and best study that compares the genetic yield potential of two elite tomato varieties in Nangarhar, Afghanistan. No study has reported yield potential of 38.06 metric tons in a Hectare (ha) in Afghanistan which suggests our study was a breakthrough in seeking the path for higher tomato productivity. Although the yield is astonishing on the country level, it is still far lower when compared with tomato productivity in countries such as the United States, Israel, Greece, France, Chile and others. Further research is required in order to improve the cultural practices of tomato for yield optimization.

CONCLUSION

This study was conducted to evaluate the genetic yield potential of two elite tomato varieties in Nangarhar, Afghanistan. The CXD_222 variety showed significantly higher yield than Roma_VF. Studied parameters revealed that the yield enhancement in CXD_222 was due to higher number of fruit production per plant.

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