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GROWTH AND YIELD STABILITY OF TOMATO (*SOLANUM LYCOPERSICUM* L.) GENOTYPES IN LATE AND EARLY PLANTING SEASONS IN A HIGH RAINFALL AND HUMID RAINFOREST ZONE

E.E. Goodlife, V. Wilson and E.T. Jaja
Department of Plant Science and Biotechnology, Rivers State University, Port Harcourt, Rivers State, Nigeria

Correspondence: victoriawilson.2005@gmail.com

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ABSTRACT

This experiment was conducted in the late and early seasons of 2021 and 2022, respectively in the Department of Plant Science and Biotechnology, Rivers State University, Port Harcourt. Four tomato genotypes NHTO 0201, B52, NHTO 0294 and Thorgal F_1 hybrid were raised for six weeks and transplanted into plastic bags filled with 10 kg of soil and laid out in a CRD in the field with each treatment replicated six times. Data were analysed using ANOVA at p=0.05 in a CRD factorial arrangement with planting season as Factor A and genotype as Factor B. Plant height, number of leaves/plant, number of branches/plant, number of days to 50% flowering, days from flowering to fruiting and number of fruits/ plant were significantly higher in the early season than in the late season. Tomato genotypes showed significant differences in number of leaves/plant, number of branches/plant and number of flowers/plant. Planting season by genotype interaction was significant for Number of leaves/plant and number of fruits/ plant. In the late season, B52 had the highest yield stability of 2.857, whereas in the early season, NHTO 0294 had the highest yield stability of 2.121. Averaging for both seasons, B52 had the highest yield stability of 2.107. For stable yield in both seasons, the B52 genotype is recommended, being the one with the highest yield, most stable and well adapted. It could be used as a breeding material for improving tomato production in the high rainfall region.

Key words: Tomato genotype; planting season x genotype interaction; yield stability performance
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INTRODUCTION

The Savannah agro-ecological region in Nigeria is considered the best place to grow tomatoes (*Solanum lycopersicum* L.) because of the climatic conditions and because there are fewer pests and diseases that affect them there than in other parts of Nigeria (Wokoma, 2008). Major production zones lie between latitudes 7.5°N and 13°N with temperature range of 25°C-34°C, 700 mm-1,052 mm annual rainfall and relative humidity of 45-73% (Sowumi and Akintola, 2010). Northern states, especially Kaduna and Kano, produce most of the tomatoes in Nigeria. However, the high rate of insecurity (Boko Haram insurgency, bandit attacks, farmer-herder clashes, kidnappings and killings of farmers in their farms, etc.) which began in North-Eastern Nigeria in 2009, caused the dislocation of many farm families, making it difficult for them to access their farmlands. This, in turn, has led to food insecurity and a decrease in tomato production (Ojo, 2020; Ladan and Badaru, 2021). There is an urgent need, therefore, to increase and expand cultivation of tomatoes beyond the savannah region into the humid tropical monsoon climate region in coastal states like Rivers State (Falaiye *et al*., 2021; Nwuche and Daminabo, 2022). Among the most cost-effective and more sustainable ways to increase production of tomato and expand the area under cultivation is the use of genotypes resistant to pests and diseases, with good fruit quality, environmental adaptation and yield stability.

The conundrum though is that the humid and high rainfall environment in the tropical monsoon rainforest region of Port Harcourt (latitude 4.847^{o}N and Longitude 6.975^{o}E) is considered unsuitable for tomato production because of the attendant high annual rainfall of over 2,369 mm - 2,500 mm, temperatures ranging from 25^{0}C–28^{0}C and relative humidity of 80-85% (Ugonna *et al*., 2015) resulting in the extremely low tomato production in the region. They suggested that for field cultivation in Nigeria, August and September could be the prime planting months in high rainfall regions. There is a need for more research to confirm this claim given the evolving climate change phenomenon. Studies have shown that temperature especially day and night-time temperatures, high rainfall and high relative humidity can substantially inhibit reproductive organs of tomatoes especially viability of pollen and female fertility, thereby impacting flowering negatively (flower abortion and reduction in flower clusters); pollination and fertilisation (damaged pollen grains, non-release of pollen, poor development of pollen tubes, etc), resulting in poor pollination fertilisation of the stigma. All of these lead to severe reduction and even complete absence of fruit set, fruit formation and fruiting in tomato because flowers fail to develop into fruits resulting in decreased productivity (Sato *et al*., 2000; Firon *et al*. 2006; Jones, 2008: Ozores-Hampton *et al*., 2012; Kugblenu *et al*., 2013; Ozores-Hampton, 2014; Isa *et al.*, 2017; Xu *et al*., 2017). A combination of these three environmental factors at high levels also encourages development of diseases and pests (Sato *et al*., 2006; Wokoma, 2008; Ajayi and Hassan, 2019). Researchers (Selamawit *et al*., 2017; Sora, 2018; Ketema and Beyene, 2021; Bihon *et al*., 2022) have emphasised the need to find and exploit genotypes of tomato that are high-yielding and adapted to the humid high rainfall climate, agro-ecology and soil type, pests and diseases predominant in such regions.

Among the new approaches in the breeding of tomato is the emphasis on sustainable production and/or adaptation to adverse environmental conditions resulting from climate change (Yan, 2014; Mata-Nicolás *et al*., 2020). The goal of plant breeding is to select genotypes that are stable across a particular set of environments or that have high performance in target environments. Yield stability is described as tenacity in the presence of environmental changes resulting in decreased genotype-by-environment interactions and boosted fitness (Fasoula and Fasoula, 1997; Fasoula and Fasoula, 2002). Breeders are also interested in stable genotypes, given that such genotypes are among the winner genotypes (Fasoula and Tokatlidis, 2012; Avdikos *et al*., 2021**)**. This experiment was carried out to investigate the growth and yield stability of tomato genotypes in the early and late-planting seasons in the humid and high rainfall conditions of Port Harcourt, Rivers State, Nigeria.

MATERIALS AND METHODS

Site Description

The experiment was carried out in the open field of the Botanical Garden of the Department of Plant Science and Biotechnology, Rivers State University, Port Harcourt, Nigeria. Port Harcourt lies towards the coast in the Niger Delta Region at latitude 4.847°N and longitude 6.975°E. Port Harcourt has heavy rainfall with annual rainfall ranging from 2,369 mm-2,500 mm. The rainy season lasts approximately 8 months from March to October, although even the supposed dry season in the months of November to February is not free from sporadic heavy rainfall. The annual temperature range is between 25°C-30°C, annual relative humidity is 80-85% and annual solar radiation is 9.25 mJm^{-2}/day lasting for 4 hours (Ogungbenro and Morakinyo, 2014; Kolebaje *et al*., 2016; Daramola *et al*., 2017; Chinago, 2020; Johnson *et al*., 2021; Nwuche and Daminabo, 2022).

Experimental Materials and Design

Seeds of the four tomato genotypes: F_1 hybrid Thorgal from Agriseed Ltd., Technisem in France; while NHTO 0294, NHTO 0201 and B52 were obtained from the Genetic Resources Unit (GRU) of the National Institute of Horticultural Research and Training (NIHORT), Ibadan, Oyo State, Nigeria. In 2021 late planting season, seeds were sown in individual perforated plastic containers of 16.5 cm x 11.5 cm x 5 cm containing sandy-loam soil on 24th of September, 2021 and six weeks after planting, the seedlings were transplanted on 6th November 2021, into perforated black polyethylene bags of 55 cm x 45 cm x 45 cm filled to three-quarter level with 10 kg of sandy-loam soil at the rate of a seedling/ bag. In the early planting season of 2022, seeds were sown on 2nd of April, 2022, and seedlings transplanted after six weeks on 14th May, 2022. The four tomato genotypes were each replicated six times and arranged in a Completely Randomised Design. Weeding was done when necessary. No soil amendments, pesticides or fertilizers were applied. During fruiting, staking was done to prevent plants from lodging.

Data Collection and Statistical analyses

Data collected included plant height, number of leaves/ plant, branches/ plant, days from planting to 50% flowering, flowers/plant, days from flowering to fruiting, days from planting to fruiting, days from planting to fruit maturity, days from fruiting to fruit maturity and number of fruits per plant. Yield stability performance was estimated as

the standardised mean of individual plants among individual plants of a crop stand (Fasoula and Fasoula, 2002; Fasoula and Tokatlidis, 2012; Avdikos *et al*., 2021).

$$\text{Yield stability} = \frac{\text{Mean yield } (\bar{x})}{\text{Standard deviation (sd)}}$$

All data were analysed using the analysis of variance to test for significance at 5% and 1% levels of significance in a completely randomised design in a factorial arrangement with planting season (late season planting and early season planting) as Factor A.

Tomato genotype (F_1 hybrid Thorgal, NHTO 0294, B52, and NHTO 0201) was factor B; giving a 2 x 4 factorial allowing all the factors to be tested together to determine seasonal and genotypic effects as well as interactions. An interaction between 2 factors can be measured only if both are tested together in the same experiment. Where the F-test was significant, the means were compared using the least significant difference (LSD) test at the 0.05 and 0.01 levels of probability.

RESULTS

In Table 1 shows the effects of planting season and tomato genotype on the number of days from planting to fruiting, days from planting to fruit maturity, and days from fruiting to fruit maturity. These traits did not differ significantly with planting season and tomato genotype and there were no significant interaction effects between planting season and tomato genotype.

Plant height

Tomato plants grown in the early season (April) were significantly taller ($p<0.05$) than those planted in the late season (September) in all genotypes. (Table 1). The heights of the tomato genotypes in the late planting season were not significantly different from each other. Also, in the early planting season height of tomato genotypes did not differ from each other. Tomatoes grown in the early planting season were significantly taller than those grown in the late planting season.

Number of Leaves per Plant

The number of leaves of all genotypes of tomato grown in the late season was significantly less ($p<0.05$) than that at the early season (Table 1). There was at least a 50% reduction in the number of leaves of each tomato genotype grown in the late season when compared with the early season. The NHTO 0294 had the highest reduction in the number of leaves in the late season (289 %). The tomato genotypes showed significant differences in the number of leaves only in the early planting season. The NHTO 0294 genotype had significantly the highest number of leaves in the early season. The NHTO 0201 and B52 genotypes did not differ significantly in the number of leaves. The Thorgal F_1 hybrid had the lowest number of leaves.

Number of Branches per Plant

Tomato cultivated in the late season in 2021 had a significantly fewer ($p< 0.05$) branches than those of the early season in 2022 in all genotypes of tomato (Table 1). The number of branches of early season tomato plants was 100% more than those of the late season except in the case of B52 genotype which had only 67% more and for NHTO 0294 which had up to 250% more. In the early season, NHTO 0294 had significantly more branches than the B52 and the Thorgal F_1 hybrid. The branches of Thorgal F_1 hybrid were significantly the lowest in both seasons.

Number of Flowers per plant

There were no significant differences ($p<0.05$) in the number of flowers in both seasons (Table 1), although significant genotypic differences were observed in the number of flowers. In both planting seasons, the B52 genotype had the highest number of flowers

Days from planting to flowering

All tomato genotypes grown in the late season of 2021 flowered between 65 and 85days whereas those planted in the early season of 2022 flowered 83-89 days after planting (Table 1). Generally, tomato plants flowered earlier in the late season with NHTO 0201 and NHTO 0294 genotypes flowering 24 and 21 days earlier, respectively. Significant differences ($p<0.05$) were observed in the number of days from planting to flowering of tomato genotypes in the early season compared to the late season except for the Thorgal F_1 hybrid and B52 genotypes. Days to flowering in both seasons did not differ significantly for B52 and the Thorgal F_1 hybrid.

Days from Flowering to Fruiting

The number of days from flowering to fruiting in all tomato genotypes in the late season increased when compared with the early season (Table 1). Whereas the number of day flowering to fruiting in the early season of 2022 ranged from 4-9 days for the tomato genotypes, it took between 8-15 days in the 2021 late season. However, only NHTO 0294 recorded a significant difference ($p<0.05$) of over 300% increase in days from flowering to fruiting in both seasons.

Number of Fruits per Plant

The number of fruits per plant in all tomato genotypes in the early season was higher than in the late season (Table 1). Whereas fruits per plant varied from 3-8 in the tomato genotypes in the early season, it ranged from 1-4 in the late season. However only B52 and NHTO 0294 genotypes showed significant differences ($p<0.05$) when compared with the early and late seasons. Whereas fruits per plant in B52 genotype declined by 100% in the late season, that of NHTO 0294 declined by 250%.

Planting Season x Tomato Genotype Interaction

The interaction effects between planting season and tomato genotype were not significant ($p>0.05$) for plant height, branches/plant, days from planting to flowering and days from flowering to fruiting of tomato plants. However, significant ($p<0.05$) interaction effects of planting season and tomato genotype were observed in the number of leaves produced (Fig 1) and in the number of fruits per plant (Fig 2). The NHTO 0294 and B52 genotypes showed a higher decrease in number of fruits per plant in the late season than in the early season.

Yield Stability Performance

Yield stability of tomato genotypes in the late planting season of 2021 and early planting season of 2022 is presented in Table 2, In the late season, B52 had the highest yield stability of 2.857, whereas in the early season, NHTO 0294 had the highest yield stability of 2.121.

DISCUSSION

The growth performance of tomato genotypes in the field was assessed in the late and early planting seasons in Port Harcourt, a high rainfall and humid rainforest region.

Vegetative growth in the 2022 early planting season was significantly higher than in the late planting season of 2021 for all tomato genotypes as indicated by vegetative traits, like plant height, number of leaves and branches. This could be attributed to availability of water and higher relative humidity in the early planting season than the late planting season or dry season. Generally, the amount of rainfall in Port Harcourt increases from February, peaks in September and declines thereafter from October to December (Johnson *et al*., 2021; Nwuche and Daminabo, 2022). The number of leaves and branches which are indicative of luxuriant vegetative growth with adequate water (Sánchez-Rodríguez *et al*., 2011; Chand *et al*., 2021) declined by at least 50% in all tomato genotypes in the 2021 late planting season compared to the 2022 early planting season, with NHTO 0294 being the worst affected indicating, perhaps, that it is the most susceptible to water stress. Zhang *et al*. (2018) and Liang *et al*. (2020) reported that low water availability reduced plant growth by limiting photosynthetic rate. Similar results of lower vegetative growth in the late season have been reported by Oladitan and Oluwasemire (2018) for tomato varieties grown in the transition zone of the derived savannah/rainforest region of Nigeria.

Significant genotypic differences were observed in the number of leaves and branches in the 2022 early season. Although the number of leaves produced in NHTO 0201, B52 and NHTO 0294 was comparably high in the early planting season, there was a sharp decline in the late planting season in the three genotypes. This could have been due to changes in weather conditions such as reduction in rainfall, water availability, higher temperature and lower relative humidity. However, the F_1 hybrid Thorgal did not show significant decrease in the number of leaves in the late season as did the other three genotypes. Poiroux-Gonord *et al*.(2010) and Ripoll *et al*. (2014) suggested that the varying responses of tomato genotypes to inadequate water availability as well as other abiotic stresses should be thoroughly investigated in order to identify and develop genotypes that are adapted to such conditions. This study showed that there was a significant interaction of planting season and tomato on the number of leaves and branches, indicating that the genotypes responded differently to seasons. Significant planting season x genotype interactions poses a challenge to breeders (Baraki *et al*., 2014). Gur *et al*. (2011) and Albert *et al*. (2016) observed that interaction between genotype and environment was significant for some traits such as fresh weight of fruit, primary and secondary metabolism contents and firmness of fruits. Phenological traits such as flowers per plant, days from planting to fruiting, days from planting to fruit maturity and days from fruiting to fruit maturity did not differ significantly between the early and late planting seasons. However, days to flowering and days from flowering to fruiting showed significant differences between the planting seasons. Tomatoes grown in the late planting season flowered earlier than those grown in the early planting season. The number of days from flowering to fruiting increased significantly in the late planting season compared to the early planting season. Lower precipitation and relative humidity in the late season favoured early flowering but delayed fruiting as reported by Oladitan and Oluwasemire (2018). With respect to yield stability among the tomato genotypes, the genotype combining the highest mean yield ($\bar{\mathbf{x}}$) with the highest yield stability performance ($\bar{\mathbf{x}}$/sd) is the most stable and productive. An ideal genotype should always combine high yield with stability of performance. The B52 genotype had the highest yield, followed by the NHTO 0294. Across both seasons, the B52 genotype had the highest yield stability and was the most stable and productive (Fasoula and Fasoula, 2002; Fasoula and Tokatlidis, 2012; Avdikos *et al*., 2021).

CONCLUSION

This study identified the tomato genotype B52 with the highest yield, in both late and early planting seasons. This genotype could be used as a breeding material in future tomato breeding programmes. Significant planting season x genotype interactions showed that genotypes responded differentially to the changes in the seasons.

Table 1. Mean sum of squares from ANOVA of growth and yield stability of tomato genotypes in late planting season of 2021 and early planting season of 2022 in the high rainfall and humid rainforest of Port Harcourt

Sources of Variation	df	Plant height	No. of leaves/plant	No. of branche/ maturity	No. of days to 50% flowering	No. of flowers / plant	No. of days from flowering to fruiting	No. of days from planting to fruiting	No. of days from planting to fruit maturity	No. of days from fruiting to fruit maturity	No. of fruits / plant
Planting season (A)	1	3879.3**	9695.1**	88.5**	1938.0*	3.0 ns	288.1*	852.6 ns	4427.5 ns	160.2ns	67.4*
Tomato genotype (B)	3	55.0 ns	1855.8**	19.3**	262.9 ns	5.0*	35.6 ns	942.5 ns	4687.4 ns	326.1 ns	12.3ns
(A x B) Interaction	3	77.0 ns	978.9**	6.0 ns	390.2 ns	3.2 ns	47.6 ns	367.4 ns	3032.9 ns	204.3 ns	52.5**
Error	40	95.4	184.9	2.9	285.5	1.7	40.7	1059.1	1947.3	182.8	10.7
CV%		13.3	15.3	12,4	11.1	13.9	10.9	10.2	12.0	12.0	11.9

* Significant at *P* =0.05; ** Significant at *P* =0.01; ns = not significant; cv% = coefficient of variation

Table 2. Yield stability performance of tomato genotypes in late planting season of 2021 and early planting season of 2022

Planting Season	Tomato Genotype	Mean Number of Fruits/ plant (x̄)	Standard Deviation (sd)	Yield Stability Performance (x̄/sd)
Late Planting	NHTO 0201	1	1.2	0.833
	B52	4	1.4	2.857
(2021)	NHTO 0294	2	2.3	0.870
	F1 THORGAL	1	1.3	0.769
Early Planting	NHTO 0201	4	4.9	0.816
(2022)	B52	8	5.9	1.356
	NHTO 0294	7	3.3	2.121
	F1 THORGAL	3	2.4	1.250

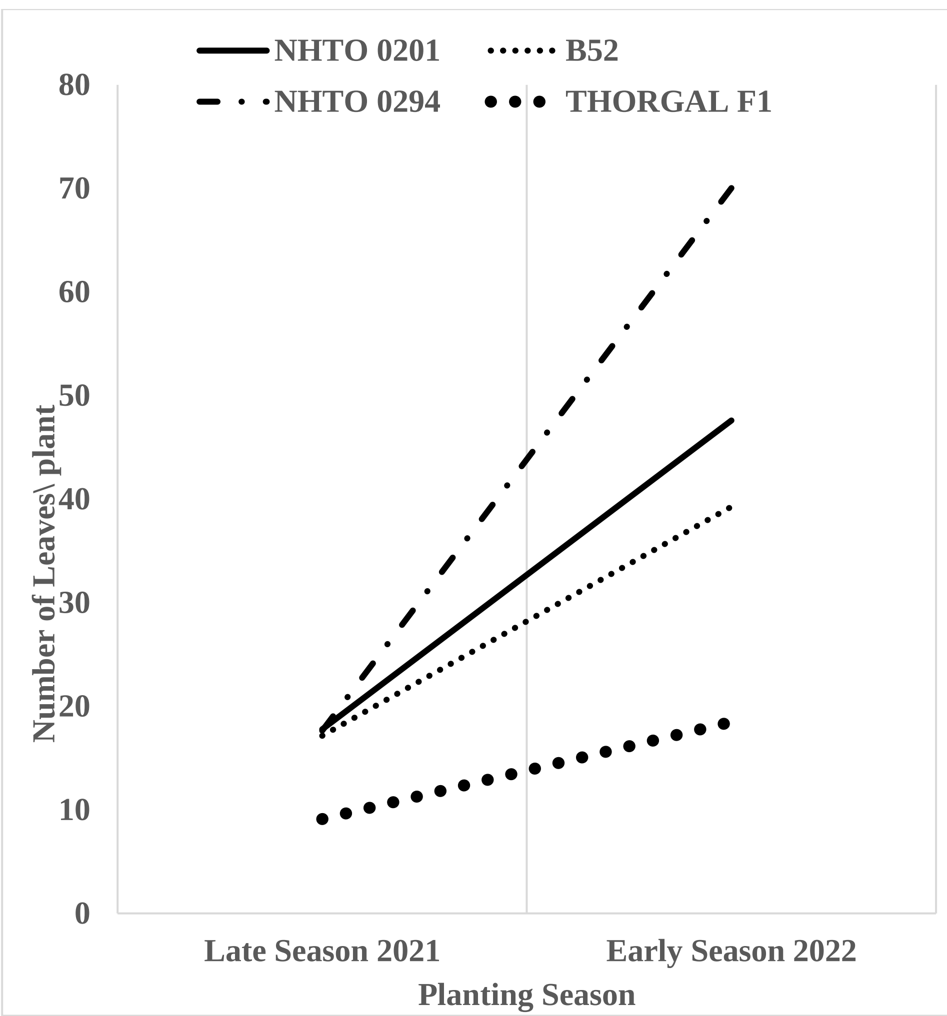

Fig 1. Interaction effects of planting season and tomato genotype on number of leaves per plant

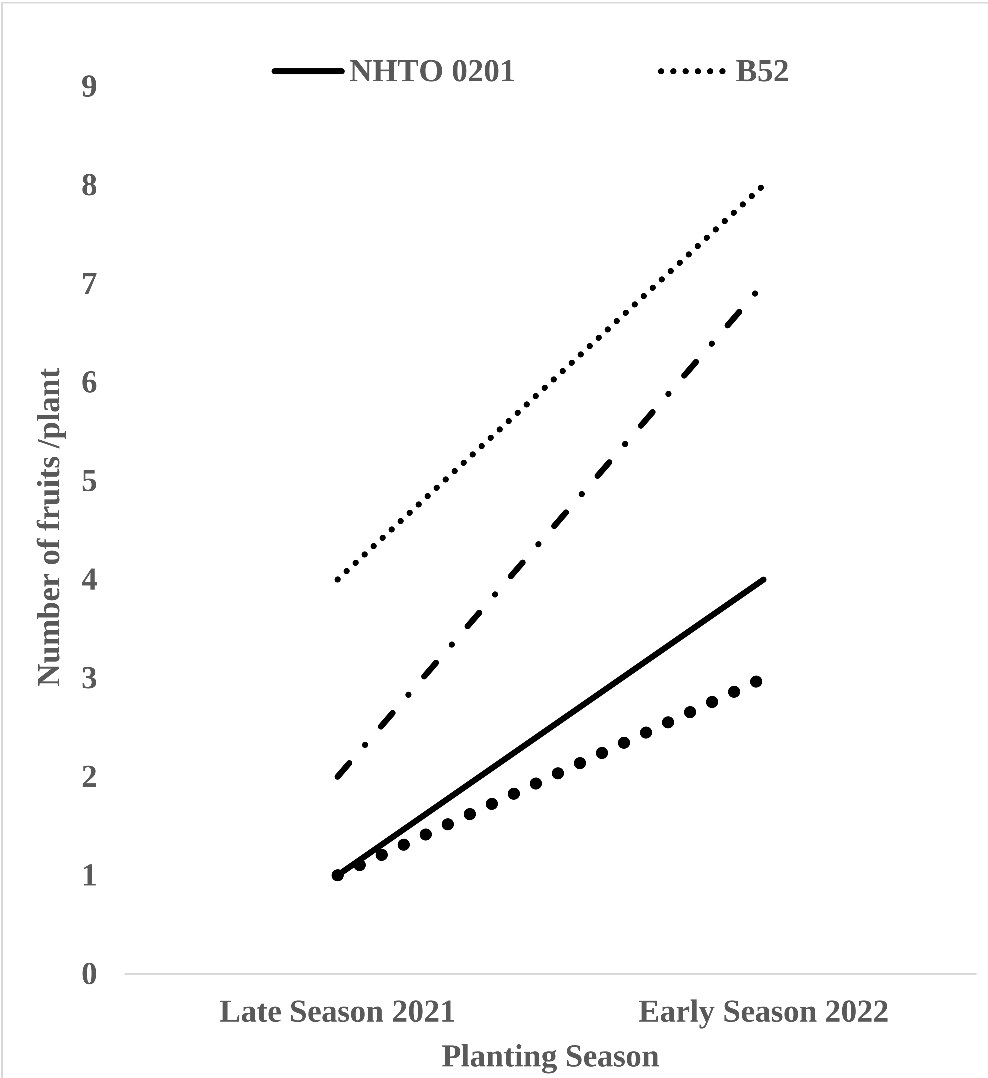

Fig. 2. Interaction effects of planting season and tomato genotype on number of fruits per plant

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