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Influence of organic and inorganic fertilizer on agronomic traits and salt tolerance of tomato (*Lycopersicon esculentum* L.)

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Abstract

Salt stress is one of major abiotic threats to crop productivity globally. The effect of Arbuscular mycorrhizal fungus (AMF), NPK and Compost on salt tolerance of tomato at 100 mM was investigated. The study aimed at improving tomato growth and yield under continuous irrigation system, this was done by applying NPK (16 g), compost (150 g) and AMF (20 g). the growth data collected on agronomic trait were subjected to analysis of variance (ANOVA), principal component analysis (PCA) and correlation. The results obtained revealed that compost only had the highest yield of 101.80 g in non-saline condition, followed by the combination of compost and NPK with yield of 91.99 g under saline condition, while saline solution only had the lowest yield (2.25 g). The relative discriminating power of the PCA as revealed by Eigen value was 4.19, 1.40 and 1.00 for PC1, PC2 and PC3, respectively with corresponding contribution of 52.38%, 18.43% and 11.98%, respectively. The first three PCs accounted for 83.79% of the total variation. PC1 was associated with number of leaves, plant height, stem girth and number of fruits. PC2 was linked with fruit and shoot fresh weight with negative loading and root fresh weight with positive loading, while PC3 was responsible for the number of fruits with negative loading and number of flowers with positive loading. Fruit fresh weight showed a strong positive correlation with all agronomic traits assessed, except for the root fresh weight. Therefore, identified traits can be useful in tomato improvement programs for indirect selection of yield improvement. Also, combination of compost/AMF with NPK fertilizer can enhance performance of tomato plants and serve as buffer to withstand salt stress for more productivity.

Introduction

Tomato (Lycopersicon esculentum L.) is one of the most commercially cultivated vegetable crops in the family Solanaceae (Tanuja-Buckseth, 2023). Globally, there are more than 3000 species of tomatoes, other popular species in this family include potato, tobacco, peppers, and eggplant (Priya et al., 2016).

Tomato is a branching herbaceous plant, and the growth habit ranges between erect and prostrate. Its stem is green and covered with glandular trichomes. It can survive a wide range of climatic conditions from temperate to hot and humid tropical (Navas et al., 2022).

According to FAOSTAT (2022), the world produced 186.821 million metric tonnes of tomatoes on 5,051,983 hectares in 2020 with an average yield of 37.1 metric tonnes/hectare (mT/ha) while Africa alone produces 21 million tons from 1.3 million hectares (FAO, 2017). Global production of tomato reported that China is the highest producer with 648,658.07mT in Asia, followed by Italy in Europe with 624,791.0mT and Egypt has highest of 6731220mT in Africa amongst others (Parma, 2022). Nigeria produced

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369,372.2mT of tomato that is consumed by about 220million population with per capita consumption of 0.0184tons/year (FAOSTAT, 2022). Tomatoes can make an important contribution to a healthy diet and can be consumed raw or as processed products such as juice, and soup while still maintaining their nutritive value (Atta et al., 2023) and are of good source of phytochemicals and nutrients such as lycopene, potassium, iron, folate, and vitamin C (Bhowmik et al., 2012). Tomatoes are rich in bioactive substances that are essential for human health, weight loss, and healthy skin, these compounds are known to have anticancer and antioxidant properties and can improve or avoid multiple long lasting degenerative diseases (Ali et al., 2021). In Nigeria, tomatoes command a huge demand especially in the urban areas where it is sought after by households to prepare their favourite meals (Atta et al., 2023).

Salinization of soil (a result of the accumulation of water-soluble salts in the soil) is a serious problem and it's increasing steadily in many parts of the world, particularly in arid and semi-arid areas (Singh, 2021). It is estimated that by 2050, about 50% of all arable land will be impacted by salinity (Butcher et al., 2016). Soil salinity is one of the major abiotic threats caused by multiple factors including drought, water shortages, and the use of poor-quality water for irrigation (Russo, 2023), it also inhibits and suppresses plant growth, and can lead to plant death (Oyetunji et al., 2023). Soil salinization is among the main issues hampering the production of tomato in many countries around the world and it varies significantly between tomato varieties (Bogoutdinova et al., 2024). The application of synthetic fertilizers, while providing essential nutrients, may not adequately address the challenges of salt stress in tomato plants as its excessive use is a threat to the environment and plants (Amirahmadi et al., 2023). Exploring alternative approaches is necessary to adequately mitigate the negative impact of salt stress. Numerous studies have been carried out to understand the response of tomato to saline stress, application of compost and Arbuscular Mycorrhizal Fungus (AMF) (Gedeon et al., 2022; Liu et al., 2023). AMF forms symbiotic relationships with plant roots, enhancing nutrient uptake and water acquisition (Shrivastava and Kumar, 2015), it also improves plant tolerance to various stresses, including salinity (Smith and Read, 2008). Compost, an organic fertilizer capable of improving soil structure, nutrient availability, and promoting beneficial microbial activity, mitigates the negative effects of salt stress on tomato (Egamberdieva et al., 2017). There is dearth of information on the synergistic effects of the combination of compost, AMF and NPK fertilizer on tomato tolerance to salt stress. Principal component analysis has been used by different researchers to identify characters with the highest contributions to the variation observed in germplasms (Akinyosoye et al., 2017; Okunlola et al., 2020). Therefore, principal component (PC) and correlation analyses were used to investigate the effect of the interaction of arbuscular mycorrhiza (AMF), compost and NPK fertilizer on agronomic trait and salt tolerance of tomato to enhance sustainable and salinity-resilient tomato production in Nigeria.

Methods and Materials

Experimental site

The study was conducted at the Botanical Nursery of the Department of Botany, University of Ibadan, Ibadan, Nigeria. The study site lies approximately between longitude 7.44o and latitude 3.90° E with elevation ranging from 205m -227m above sea level

Source of materials

Plum tomato seeds were purchased from Bodija market in Ibadan, Oyo state. Soil sample was collected at the experimental site. Arbuscular mycorrhizal fungus (AMF) inoculum (Glomus mosseae) was gotten from the same department. Salt (NaCl) was purchased from a scientific laboratory at Ibadan, Oyo state, Nigeria. Fertilizing compost (Tithonia diversifolia and poultry manure) was sourced from the same department, while NPK 15-15-15 fertilizer was bought from Ogunpa market in Ibadan.

Experimental design and agronomic practices

10 kg of soil from the same source was weighed each into 58 polyethylene bags (10 polyethylene bags as nursery pots and 48 as experimental pots) and holes were made at the bottom and sides to allow drainage of excess water and good aeration. The pots were watered and kept on the field for 24hours. Twenty seeds were

sown each into the nursery pots and watered daily. The experimental pots were arranged in a completely randomized design (CRD) and tagged based on the treatment in four replications. The seedlings were maintained in the nursery for three weeks. The treatments used were Salt (S), compost, NPK fertilizer and AMF inoculum and they were added in the following combinations; S + AMF, S + NPK, S + Compost, S + NPK + AMF, S + Compost + AMF, S + NPK + Compost, S + NPK + Compost + AMF and Control, all the treatments were applied one week after transplanting.

After twenty-one days of nursery period, two seedlings were transplanted per pot. The AMF inoculation was prepared by adding 20 g of the inoculum to the soil below the root of the tomato seedlings before covering with soil (Sankaranarayanan and Rajeswari, 2010). Thinning was done one week after transplanting and treatments were applied immediately (Mona et al., 2018). Also, the plantlets were supplied with 150 g and 16 g of compost and NPK fertilizer respectively (Kashif, 2019). Salt stress was imposed by irrigating the tomato plant with 100 ml of 100mM (Sholi, 2012) NaCl solution every three days. The tomato plantlets that were not irrigated with saline solution were watered at regular interval using tap water.

Data collection

The vegetative and reproductive parameters were taken at 6 and 8 weeks after planting (WAP), respectively. Data were collected as follows: The vegetative parameters such as number of leaves per plant (was determined by counting the number of leaves taken from five plants at random and mean was calculated); plant height (average of five randomly selected plants measured with a transparent ruler and taken in centimeters from ground level to the tip of the plant) and stem diameter (was taken at the mid-stem of the plant with the use of a vernier caliper in mm and then converted to cm). The reproductive parameters such as number of flowers per plant (was determined by counting the number of flowers taken from five plants at random and average was calculated), number of fruits per plant (was determined by counting the number of fruits taken from five plants at random and average was calculated), the following parameters were determined by weighing and recorded in grams: fruit fresh weight, root fresh weight and shoot fresh weight.

Statistical analysis

Data obtained were subjected to analyses of variance using the Statistical Tool for Agricultural Research (Version: 2.0.1). Means were separated using Tukey's honest significant difference (HSD). Principal component (PC) analysis was carried out, where Eigen values ≥ 1.0 were selected, while PC >0.6 were considered as the major contributors to the total variation and were selected (Matus et al. 1999). Pearson Correlation analysis was carried out to assess associations among the agronomic traits of tomato evaluated.

Results

Analysis of variances, mean performance and coefficients of variation for yield and yield contributing traits of Tomato

The analysis of variances, mean performance and coefficients of variation for yield and yield contributing traits of tomato are presented in Table 1. The results obtained revealed that the highest number of fruits (5.42) and fruit fresh weight (101.80 g) were recorded in only compost treated plant, which were statistically significant. AMF treated plant had the highest root fresh weight (52.90 g) which was statistically different from others. The highest shoot fresh weight (141.70 g) was observed in the tomato plant treated with salt in combination with NPK and compost. The highest number of leaves (164) was recorded in tomato treated with salt in combination with NPK fertilizer and compost while it was not statistically different from tomato treated with compost only (161). Also plant height was highest in the tomato treated with compost (28.90 cm). The thickest stem girth was recorded in the plant treated with compost (0.63 cm), while highest number of flowers was recorded in compost treated tomato plant (5.98).

The coefficient of variation ranged from 4.49 (shoot fresh weight) to 78.99 (number of fruits). Number of leaves (NL), plant height (PH), stem girth (SD), number of leaves (NFLO), number of fruits (NFRU),

Table 1: Means values of interaction of amendments on agronomic traits of tomato

Treatments	NL	PH	SD	NFLO	NFRU	FFW	RFW	SFW
AMF	127.68ab	23.23ab	0.51ab	5.33a	2.17ab	29.00e	52.90a	18.77f
Compost	161.20a	28.90a	0.63a	5.98a	5.42a	101.80a	13.17cde	64.40b
Control	52.67b	17.64ab	0.45ab	2.58a	1.08ab	17.74g	8.57ef	23.4f
NPK	99.58ab	27.09a	0.50ab	3.25a	3.02ab	21.14g	13.08cde	23.92f
Salt (S)	40.42b	14.50b	0.39b	2.42a	0.63b	2.25h	5.06f	11.09g
S + AMF	71.42ab	22.70ab	0.42ab	4.50a	1.75ab	2.26h	46.30b	12.05g
S + Compost	82.17ab	22.44ab	0.43ab	3.58a	1.17ab	35.42d	17.20c	56.64c
S + Compost + AMF	71.83ab	19.87ab	0.49ab	3.83a	2.00ab	81.41c	11.11de	61.37bc
S + NPK + AMF	71.17ab	23.83ab	0.45ab	3.58a	1.25ab	35.77d	14.46cd	39.62d
S + NPK + Compost	164.20a	26.87a	0.54ab	4.92a	1.83ab	91.99b	18.44c	142.70a
S + NPK	91.35ab	19.37ab	0.43ab	2.83a	0.67b	21.99fg	10.79def	32.12e
S + NPK + Compost + AMF	60.60b	21.42ab	0.50ab	5.25a	1.83ab	27.87ef	17.90c	60.01bc
Mean	91.19	22.32	0.48	4.01	1.9	39.05	19.08	45.51
Minimum	38.25	12.7	0.34	1	0.15	0.25	3.06	9.09
Maximum	215.3	30.9	0.71	6.75	7.25	103.8	54.9	144.7
CV%	36.58	17.62	15.64	32.91	78.99	5.12	10.46	4.49
Prob (0.05)	0.001	0.007	0.047	0.037	0.048	0	0	0

Means with the same letter in the same column are not significantly different at p<0.05. Number of leaves (NL), plant height (PH), stem girth (SD), number of leaves (NFLO), number of fruits (NFRU), fruit fresh weight (FFW), root fresh weight (RFW) and shoot fresh weight (SFW)

Table 2: **Eigen Values, Percentage of Variance and Cumulative Percentage of Tomato as influenced by organic and inorganic fertilizer and salt tolerance**

	PC 1	PC 2	PC 3
Eigen values	4.19	1.47	1
Variation percentage	52.38	18.43	11.98
Cumulative percentage	52.38	70.81	82.79

Table 3: **Characters with respect to Principal Component of Tomato as influenced by organic and inorganic fertilizer and salt tolerance**

TRAIT	PC1	PC2	PC3
Number of leaves	-0.41	0.05	-0.05
Plant height	-0.41	0.18	-0.22
Stem diameter	-0.43	0.06	-0.18
Number of flowers	-0.29	0.23	0.61*
Number of fruits	-0.38	0.17	-0.51
Fruit fresh weight	-0.38	-0.4	0.17
Root fresh weight	-0.08	0.70*	0.35

*component contributors

fruit fresh weight (FFW), root fresh weight (RFW) and shoot fresh weight (SFW)

Principal component analysis (PCA) for agronomic characters of tomato

The first three principal components (PC) with Eigen values greater than 1.00 accounted for about 83.79% of the total variation. The relative discriminating power of the PCA as revealed by Eigen value was 4.19, 1.47 and 1.00 for PC 1, PC 2 and PC 3 respectively with corresponding contribution of 52.38%, 18.43% and 11.98% respectively (Table 2). The results obtained revealed that PC 1 was associated with Number of leaves (NL), Plant height (PH), Stem diameter (SD) and Number of fruit (NFR) with negative loadings. PC 2 was linked with the Fruit fresh weight (FFW) and Shoot fresh weight (SFW)with negative loading and Root fresh weight (RFW) with positive loading while PC 3 was responsible for the Number of fruit with negative loading and Number of flower (NFL) with positive loading. The major contributors were Root fresh weight (0.70) and Number of flower (0.61) which were linked to PC2 and PC3 respectively (Table 3)

Table 4: Pearson's Product-Moment Correlation for agronomic traits of Tomato under the influence of organic, inorganic fertilizer and salt tolerance

	FFW	NL	PH	SG	NFLO	NFRU	RFW	SFW
FFW	1	0.60**	0.47**	0.60**	0.40*	0.46**	-0.18^{ns}	0.79**
NL		1	0.72**	0.67**	0.36*	0.61**	0.23^{ns}	0.51**
PH			1	0.73***	0.39*	0.72**	0.24^{ns}	0.39**
SG				1	0.54**	0.77**	0.06^{ns}	0.40**
NFLO					1	0.27^{ns}	0.37**	0.31^{ns}
NFRU						1	0.12^{ns}	0.17
RFW							1	-0.19^{ns}
SFW								1

NL, PH, SG, NFLO, NFRU, FFW, RFW and SFW were number of leaves, plant height, stem girth, number of flowers, number of fruits, fruit fresh weight, root fresh weight and shoot fresh weight respectively.

Correlation among agronomic traits of tomato

The correlation coefficients among the agronomic traits of tomato are presented in Table 4. Fruit fresh weight (FFW) exhibited a strong and positive correlation with most of the traits evaluated, with the exception of root fresh weight (RFW), where the relationship was negative and non-significant. Number of leaves (NL) showed a significant positive correlation with plant height (PH) (r = 0.72). Similarly, a significant association was observed between PH and number of fruits (NFRU) (r = 0.72). Stem diameter (SD) was also significantly and positively correlated with NFRU (r = 0.77). The NL, PH, SG, NFLO, NFRU, FFW, RFW and SFW were number of leaves, plant height, stem girth, number of flowers, number of fruits, fruit fresh weight, root fresh weight and shoot fresh weight respectively.

Discussion

The compost treatment had the highest fresh fruit weight, while the salt treatment yielded the lowest. Yet, there were notable differences between both and the control experiment. Organic fertilizers are known to supply sufficient nutrients for the crop plant's healthy growth and may improve nutrient uptake, raise assimilation capacity, and stimulate hormone activity (Tomati *et al*., 1990). Additionally, it was noted that tomato fruit from plants treated with compost did not exhibit any declines, unlike those from the control and salt treatment. This is ascribed to compost's pesticide properties, which help shield crop plants from pests and diseases by suppressing, repelling or by reducing biological resistance in plants to fight or kill them (Al-Dahmani *et al*., 2003).

The study found that plants treated with combination of saline solution, NPK fertilizer, and compost had the highest shoot weight, while the lowest shoot weight was observed in tomato plants irrigated with saline solution only. Studies have shown that the fresh and dry weights of the shoot system are affected by changes in salinity concentration, type of salt, or plant species. The results align with previous studies on lettuce, cowpea, fodder beet, common vetch, and *Atriplex halimus* (Taffouo *et al*., 2010; Memon *et al*., 2010).

Contrary to what could be expected, the induction of salt stress did not have a negative effect on mycorrhizal colonization of plants treated only with AMF. This could be explained by the fact that AMF were taken from areas of saline soil and are most effective when exposed to salts (Pan *et al*., 2020).

In this study, a clear decline in tomato plant growth indicators was observed under salinity conditions. The assessment of plant salt tolerance, as mentioned by Da Silva *et al*. (2008), is often based on the biomass produced. Despite the general trend that the root parts of plants are less affected by excess salt than their aerial parts, as noted by Munns and Tester (2008), a greater vulnerability of root dry weight to salinity compared to that of leaves was revealed in this study. This peculiarity can be attributed to the predisposition of the roots to be the first to face the accumulation of salt in the soil solution (Ait-El-Mokhtar *et al*., 2019).

This results obtained in the PCA corroborates with that of Henareh *et al*. (2015), who conducted an experiment on 97 tomato land races and found three main components which explained 71.6% of total variability in principal component analysis. In another study, Mitul *et al*. (2016) tested 14 tomato genotypes and obtained three principal components explaining 79.14% of total variability.

The correlation results suggest that increases in vegetative growth traits such as number of leaves, plant height, and stem girth are closely associated with reproductive traits, particularly fruit number and fruit fresh weight. This implies that improving vegetative vigor could directly enhance fruit yield potential in tomato. Comparable findings were reported by Akinyosoye *et al*. (2025), who observed highly significant positive correlations between seed yield (r = 0.16*) and most of its yield-related components such as SY with PH (0.37**), EH (0.33**), EL (0.46**), ED (0.30**), NRPE (0.39**), NKPR (0.24**). Likewise, Mitul *et al*. (2016) reported that fruit weight exhibited a strong positive correlation with yield per plant, further supporting the outcome of this study

Conclusion

This study explored the synthetic and organic method of fertilization as a sustainable strategy of mitigating salinity stress in tomato production. By using organic (compost/AMF) combined with chemical fertilizer, tomato plants can grow well and withstand stress more adaptively. Both growth and yield traits were improved when AMF or compost was applied in combination with NPK fertilizer on salt stressed tomato plants. The combination of NPK+ compost was identified in this study as the most effective treatment to increase tomato resistance to salt stress, followed by AMF and NPK while compost alone stood out as the most effective amendment for tomato plants under non-saline condition. Therefore, it is recommended that, for optimum productivity of tomato plants under saline condition, AMF or Compost in combination with NPK be applied.

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