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Response of Tomato to Crude and Fine Phosphatic Fertilizers Integrated with Cattle Manure and Indole Acetic Acid

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ABSTRACT

Phosphatic fertilizers are an integral part of crop cycle and are responsible for food production. But due to continuous increase in prizes of fertilizer over the years, the economics of the farmer is affected and there is a dire need to find the alternate. To investigate the response of tomato (Lycopersicum esculuntum L.) to crude phosphate rock (CPR), commercial phosphate fertilizer alone, or integrated with cattle manure (CM), and indole acetic acid (IAA) an experiment was conducted in pot culture with the factors IAA and inorganic and/or organic fertilizers. A number of flowers, root length, number of fruit per plant, fruit diameter, 5 fruit weight, and fruit yield were affected by treatments. Use of commercial single super phosphate along with cattle manure fortified with IAA produced better results for growth and yield of tomato. Crude phosphate rock applied along with cattle manure and IAA performed better compared to CPR alone. Soil pH, Bulk density, organic matter and extractable phosphorus were influenced by use of treatments. Inorganic phosphatic fertilizer integrated with organic amendments performed better than the application of inorganic fertilizers and crude phosphate rock alone. Hence, it may be concluded that the integrated use of inorganic phosphatic fertilizer with manure fortified with IAA enhanced both growth and yield of tomato and also improved the soil properties.

INTRODUCTION

The tomato (*Lycopersicum esculuntum* L.) supply cycle varies in Pakistan. Mostly in early months of October and November, the price may increase and product needs to be imported. The productivity of tomatoes is low due to poor plant nutrition. In the current study, tomato is used as a test crop to evaluate the effect of phosphatic sources and organic amendment along with PGR on its growth and yield.

Mostly phosphorus requirement by the crop is fulfilled by use of commercial P fertilizers manufactured from the non-renewable rock phosphate (Wang et al., 2010; Cordell and Neset, 2014). The prices of phosphatic fertilizers have increased over the years. Cheap source of

phosphatic fertilizer is needed to increase the cost benefit ratio of farmers. Application of crude rock phosphate directly to the soil is an alternative but its solubility is low (Zapata and Zaharah, 2002). Rock phosphate contains non-exchangeable phosphate which are insoluble in water and unavailable to plants (Xuan et al., 2012).

Use of organic amendments may reduce dependency on commercial fertilizers (Almagro and Martinez, 2014). Organic amendments obtained from animal and plant origin may improve soil physical, chemical and biological attributes. Organic matter added to the soil has the potential to hold essential plant nutrients and buffer the soil to change the pH (Cole et al., 1987). Integrated use of organic amendments with inorganic phosphatic fertilizer enhances P use efficiency of plants (Horta et al., 2018). Among organic amendments cow manure has the potential to supply phosphate and improve organic matter as the C:N ratio is high (Almeida et al., 2019).

Plant growth regulators (PGRs) are used by vegetable growers to enhance tomato yield especially under high temperature. The PGRs are responsible for improved fruit setting, number of fruit, and size of fruit (Batlang, 2008; Serrani et al., 2007; Shahab et al., 2009). Plant root development is stimulated when the auxin is transported from the stem to root (Overvorde et al., 2010). Root branches may take up more nutrients from the soil (Wang et al., 2005). The IAA is produced in the apical regions of branches (Waheed et al., 2015). It is important for growth and yield and helps fruit formation (Uddain et al., 2009).

MATERIALS AND METHODS

A pot experiment to evaluate effects of crude rock phosphate, single super phosphate (SSP), organic amendments with indole acetic acid during year 2019 – 20. Tomato cv. Rio - Grande was sown on 28th November, 2019 and transplanted to the pots on 26th February 2019. It is expected to produce a fruit of approx. 1.5 kg plant^{-1}. The experiment was arranged in a completely randomized design with the factors IAA and organic, inorganic fertilizers. Indole acetic acid was applied @ 0.02% at 1 month after transplanting and at full flowering stages. The treatments were: T_1 = CPR at 120 kg ha^{-1}; T_2 = CPR at 120 kg ha^{-1}+CM @ 5 t ha^{-1}; T_3 = CPR at 60 kg ha^{-1}+CM @ 2.5 t ha^{-1}; T_4 = SSP at 120 kg ha^{-1}+CM @ 5 t ha^{-1}; T_5 = SSP at 120 kg ha^{-1}, and T_6 = SSP at 60 kg ha^{-1}+CM @ 2.5 t ha^{-1}.

Earthen pots of 2022.16 cm^3 volume were used. The pots were filled with 20 kg air dried sieved loam soil obtained from the banks of the Indus river. The Physico – chemical properties of soil are presented in Table 1. The tomato variety Rio-Grande was transplanted into the pots with 3 plants per pot. The base dose of nitrogen and potassium were added to all pots. Irrigation was applied 0.5 litre uniformly to all the pots twice a week .

Table 1

Physico – chemical characteristics of Soil prior to the experiment

Particular	Value
Soil texture	Loam
Bulk density (g cm^{-3})	1.31
$pH_{1:5}$	7.42
$EC_{1:5}$ (µS cm^{-1})	415
Organic matter (%)	0.47
Extractable P (mg kg^{-1})	5.03
Extractable K (mg kg^{-1})	160.1

Soil parameters measured after the harvest were soil organic matter using the potassium dichromate method (Nelson and Sommer, 1982), soil pH using 1:5 extract measured on pH meter (Mclean, 1982) and extractable phosphorus using a spectrophotometer (Olsen and Watanabe, 1957).

Growth and yield parameters determined were: plant height, root length, number of flowers per plant, number of fruit per plant, 5 fruit weight and fruit diameter.

The data were subjected to analysis of variance according to Steel et al. (1997) using Statistix (ver. 8.1, Tallahassee, Florida**).** If interactions were significant they were used to explain results. If interactions were not significant means were separated with least significant difference.

RESULT AND DISCUSSION

Soil Analysis Prior to Experiment

Analysis of composite soil sample was done prior to the start of the experiment, which showed that the soil was loam and bulk density of 1.31 gcm^{-3}. The $pH_{1:5}$ value was recorded 7.42, $EC_{1:5}$ 415 µScm^{-1} and soil organic matter 0.47%. Extractable phosphorus and potassium were 5.03 and 160.1 mg kg^{-1} respectively (Table 1).

Plant Height

Plant stature measured at the harvest of the crop showed non – significant changed by the application of Indole acetic acid ($P<0.05$). However, the treatments of cattle manure (CM) with crude rock phosphate (CRP) and single super phosphate (SSP) showed significant influence on plant height. The tallest plants were observed in FYM and SSP applied as full dosage (Table 2). While the least was found in CPR alone. The interaction between the IAA and fertilizer treatment were non – significant in stimulating the plant height. As plant stature is a genetical attribute, therefor the application of fertilizer treatment did not considerably influenced the height. Khan et al. (2014) found non – significant effect of fertilizer on the plant height of tomato, they consider it as the genetical characteristic. Ogundare et al. (2015) fond non – significant difference in plant height amongst the different treatment of inorganic and organic amendments.

Root Length

The root length of plant measured at the harvest of crop showed non – significant influence of IAA (Table 2). While the phosphatic fertilizer along with cattle manure and their interaction with IAA was significant at 5% level of significance. The longest root size of 20.33 cm was recorded in the treatment where sole CPR @ 120 kg ha^{-1} was used along with IAA. The smallest root length of 13.33 cm was found in SSP @ 120 kg ha^{-1} + CM @ 5 tha^{-1} in the pot without IAA. As IAA belongs to group of auxin, which has function in controlling the metabolic process, i.e. division of cell, their enlargement and growth of root (Egamberdieva, 2009). Hye et al. (2002) have reported the increase in root length by the IAA. Also, Baninasab and Mobli (2002) have reported promotion of root initiation by the use of auxin. Babatunde et al. (2019) recorded root length increase of tomato due to use of inorganic fertilizer collectively with organic amendment.

Number of Fruits Per Plant

The number of fruits recorded at the end of the experiment showed significant influence of IAA, organic - chemical fertilizer amendments and their interaction (Table 2). The greater number of fruits were 42.33 recorded in the treatment where full dose of SSP and CM were applied along with IAA. While the least number of fruits were 14.66 in the crude phosphate rock pots without IAA. Tonfak et al. (2009) found greater number of fruits in the Rio – grande by the combine application of organic manures and mineral fertilizers. Saha et al. (2019) found greater fruit of tomato per plant by application of 60% organic manures and 40% inorganic fertilizers (NPK) as compared to the application of NPK and different organic manures separately.

Fruit Diameter

The fruit diameter recorded showed significant ($P<0.05$) effect of IAA, organic manures, crude rock phosphate, inorganic P fertilizer and the interaction between them (Table 2). The greatest fruit diameter was measured 20. 82 cm in the treatment where combine use of phosphatic fertilizer and cattle manure were used @ 120 kg ha^{-1} and 5 tha^{-1} respectively. The smallest diameter

Table 2

Growth and Yield of tomato as affected by plant growth regulator (PGR) and organic or synthetic chemical fertilizers.

Plant Growth Regulator	Plant height (cm)	Root Length (cm)	No. fruit per plant	Fruit diameter (cm)	Five fruit weight (g)	Fruit yield/plant (kg)
With Indole Acetic Acid (IAA)	38.38 NS	16.2 ^{NS}	30.66 a	19.39 a	153.77 a	0.94 a
Without Indole Acetic Acid	41.15	16.7	21.33 b	18.48 b	143.47 b	0.61 b
CPR @ 120 kg ha^{-1}	33.01 d	16.0 ab	16.00 b	18.12 b	137.82 c	0.44 d
Full dose CM + CPR	35.13 cd	15.1 b	19.83 b	18.69 b	144.29 bc	0.57 cd
½ CM + ½ CPR	37.07 bcd	14.8 b	20.66 b	18.71 b	148.69 bc	0.61 c
Full CM + SSP	48.11 a	19.1 a	36.00 a	20.14 a	164.22 a	1.18 a
SSP @ 120 kg ha^{-1}	43.81 ab	17.3 ab	31.50 a	19.02 b	151.67 b	0.95 b
½ CM + ½ SSP	41.45 abc	16.5 ab	32.00 a	18.93 b	145.01 bc	0.92 b
IAA × CPR @ 120 kg ha^{-1}	33.18 ^{NS}	15.6 ab	17.33 cd	18.58 cde	144.02 bcd	0.49 ef
IAA × Full dose CM + CPR	29.83	13.3 b	20.66 cd	18.72 cde	145.60 bcd	0.60 def
IAA × ½ CM + ½ CPR	31.22	13.6 b	24.66 cd	19.01 bcd	152.22 b	0.75 cd
IAA × Full CM + SSP	52.16	20.3 a	42.33 a	20.82 a	173.45 a	1.46 a

IAA × SSP @ 120 kgha^{-1}	41.05	16.6 ab	40.33 ab	19.21 bc	152.34 b	1.22 b
IAA × ½ CM + ½ SSP	42.83	17.6 ab	38.66 ab	20.02 ab	154.99 b	1.19 b
Without IAA × CPR @ 120 kg ha^{-1}	32.83	16.3 ab	14.66 d	17.67 e	131.62 d	0.38 f
Without IAA × Full dose CM + CPR	40.43	17 ab	19.00 cd	18.67 cde	142.99 bcd	0.54 def
Without IAA × ½ CM + ½ CPR	42.93	16 ab	16.66 d	18.42 cde	145.16 bcd	0.48 def
Without IAA × Full CM + SSP	44.05	18 ab	29.66 bc	19.45 bc	154.99 b	0.91 c
Without IAA × SSP @ 120 kg ha^{-1}	46.58	18 ab	22.66 cd	18.83 bcde	151.01 bc	0.68 de
Without IAA × ½ CM + ½ SSP	40.08	15.3 ab	25.33 cd	17.84 de	135.03 cd	0.68 de

Means within a column followed by the same letter are not significantly different at 5% level of significance.

IAA = Indole Acetic acid, CPR = Crude Phosphate rock, SSP = Single Super phosphate, CM = Cattle Manure

was measured 17.67 cm in the crude phosphate rock applied pots without foliar spray of IAA. Different researchers have reported increase in fruit diameter. Choudhury et al. (2013) found fruit diameter significantly greater, where the PGR was used. Also, it has been reported by Khan et al. (2014) that significant increase was observed in fruit diameter by the combine application of FYM and inorganic fertilizer.

Five Fruit weight

The fruit weight of five tomatoes recoded from the different treatments of organic amendments, inorganic fertilizer alone and in combination with the IAA were significant different (Table 2). The greater fruit weight 173.45 g was found from the pots receiving the integrated use of SSP (120 kg ha^{-1}) and cattle manure (5 tha^{-1}). The least weight of five fruits was recorded 132.62 g in the pots receiving 120 kg ha^{-1} of CPR. The less fruit weight may be attributed to the least solubility of CPR. Naz et al. (2018) found the greater fruit weight by the application of inorganic fertilizers alone over the use of manures. Alam et al. (2020) reveled that application of IAA as foliar spray increases the yield of crop as it reduces the fruit drop and regulates the fruit setting of plant. Similarly, the use of PGR (Naphthalene Acetic Acid) showed higher fruit weight of tomato as reported by Subhash et al. (2014).

Fruit Yield Per Plant

Fruit yield per plant of tomato was significantly influenced by the application of Indole Acetic acid and organic and chemical phosphatic fertilizers. The highest yield per plant was recorded 0.91 kg in the pots receiving IAA when compared with those without IAA (Table 2). The amendments of Cattle manure along with CPR and SSP showed significant effect on the yield of tomato per plant. The highest yield of 1.18 kg was recorded where Full dose of Cattle manure with SSP was applied. The interaction between IAA and Organo – chemical amendment showed significant effect on the yield tomato. The highest tomatoes were produced in the pots where IAA was applied in combination with cattle manure and SSP fertilizer. The least was recorded in pot where CPR was added without IAA. Alam et al. (2020) reported increase in the yield tomato by the application of IAA under salinity stress. Similarly, Alhrout et al. (2018) found greater yield of tomato by the application of FYM with NPK as compared to sheep and chicken manure.

Soil Parameters as influenced by different treatments and IAA

Soil pH

Soil pH was significantly influenced by the use of commercial phosphatic fertilizer, crude rock phosphate applied sole and in-combination with the cattle manure and PGRs had significant influence on soil pH (Table 3). The phosphatic fertilizer was more effective in reducing the pH. The value of pH was recorded 7.33, the highest in the full dose of crude rock phosphate along with IAA. The least value for pH was recorded 7.10. The reduction of soil pH may be due to presence of sulphur in SSP. Han et al. (2016) reported that soil pH was significantly decrease by the application of NPK and the organic manure resulted in higher pH. Contrary to our finding organic manure reduce soil pH (Singh et al., 2015).

Bulk Density of Soil

The bulk density of soil was non significantly changed by the use of IAA application on the plants (Table 3). The treatment of cattle manure, SSP and CPR had shown significant change in the bulk density of soil under experiment. It is evident from the result that bulk density was significantly

reduced in the treatment where cattle manure was applied. In the interaction between the IAA and organo – chemical amendments the bulk density was significantly improved. The pots where half and full dose of cattle manure was applied showed decrease in bulk density. Ibrahim et al. (2020) revealed that bulk density of soil was significantly improved in cattle manure integrated with inorganic potassium fertilizer treatments.

Table 3

Soil Properties as affected by plant growth regulator and organic or synthetic chemical fertilizers

	Soil pH	Bulk Density (gcm^{-3})	Organic Matter (%)	Extractable Phosphorus ($mg\ kg^{-1}$)
PGR				
Indole Acetic Acid	7.22^{NS}	^{NS} 1.27	0.7167 ^{NS}	6.16 ^{NS}
Without Indole Acetic Acid	7.24	1.28	0.7078	6.84
Fertilizer				
CPR @ 120 kg ha^{-1}	7.29 a	1.33 a	0.53 d	5.63 b
Full dose CM + CPR	7.24 ab	1.20 c	0.76 ab	6.43 ab
½ CM + ½ CPR	7.233 ab	1.26 bc	0.80 a	6.25 ab
Full CM + SSP	7.24 ab	1.20 c	0.81 a	7.06 a
SSP @ 120 kg ha^{-1}	7.14 b	1.37 a	0.64 c	6.90 a
½ CM + ½ SSP	7.24 ab	1.25 bc	0.70bc	6.75 a
PGR × Fertilizer				
IAA × CPR @ 120 kg ha^{-1}	7.33 a	1.30 abc	0.55 de	5.57 ^{NS}
IAA × Full dose CM + CPR	7.2 ab	1.21 c	0.73 bc	6.28
IAA × ½ CM + ½ CPR	7.27 ab	1.30 abc	0.82 ab	5.66
IAA × Full CM + SSP	7.27 ab	1.20 c	0.79 ab	6.70
IAA × SSP @ 120 $kgha^{-1}$	7.10 b	1.39 a	0.64 cd	6.62
IAA × ½ CM + ½ SSP	7.23 ab	1.22 bc	0.75 ab	6.15
Without IAA × CPR @ 120 kg ha^{-1}	7.27 ab	1.36 ab	0.51 e	5.68
Without IAA × Full dose CM + CPR	7.29 ab	1.20cb	0.80 ab	6.58
Without IAA × ½ CM + ½ CPR	7.20 ab	1.23 bc	0.78 ab	6.84
Without IAA × Full CM + SSP	7.23 ab	1.21 c	0.84 a	7.42
Without IAA × SSP @ 120 kg ha^{-1}	7.18 ab	1.36 ab	0.65 c	7.19
Without IAA × ½ CM + ½ SSP	7.27 ab	1.29 abc	0.64 cd	7.35

Means within a column followed b different letter are significantly different at 5% level of significance

IAA: Indole Acetic acid CPR: Crude Phosphate rock SSP: Single Super phosphate CM: Cattle Manure

Soil Organic matter

Application of IAA showed not – significant effect on soil organic matter content. However, the effect of organic manure, inorganic phosphatic fertilizer and their interaction with IAA showed significant difference in the values of organic matter (Table 3). In the pots where cattle manure was supplemented by inorganic SSP fertilizer but without IAA showed the highest organic matter percent of 0.84%. Whereas, the sole use CPR @ 120 kg ha^{-1} the percent organic matter was recorded the least. Ali et al. (2014) also reported increase in soil organic matter with the use of compost made of organic waste. Bakayoko et al. (2009) found greater soil organic matter over control by the addition of cattle manure and poultry manure to the soil.

Extractable Phosphorus

The extractable phosphorus was recorded non – significant by the application of IAA (Table 3). Nevertheless, treatments of cattle manure, inorganic P fertilizer showed significant effect on the soil phosphorus content. The highest extractable P was recorded in full dose cattle manure along with SSP, which was statistically at par with the rest of the treatment, except crude

phosphatic rock which yield the least value for soil extractable P. Khan et al. (2014) reported non – significant effect of FYM integrated with inorganic fertilizer on the extractable soil phosphorus.

Table 4

Mean squares and ANOVA parameters for various plant and soil parameters

SOV	DF	Plant Height	Root Length	No. of Fruit per plant	Fruit Diameter	Five fruit weight	Fruit yield	Bulk Density	Soil pH	Organic matter	Extractable P
Rep	2	8.879	23.0833	48.083	34.315	9731.7	0.03466	0.00168	0.00689	0.00270	0.89654
GR	1	69.112	2.7778	784	7.5442	955.74	1.04040	0.00023	0.00134	0.00071	4.14801
Error Re*GR	2	259.71	9.6944	12.250	0.1941	17.15	0.00956	0.00368	0.04987	0.00094	0.78059
Tret	5	195.894	15.1333	399.267	2.6602	481.39	0.48874	0.02794	0.01560	0.07219	1.64190
GR*Tret	5	92.275	9.0444	60.467	0.8785	94.34	0.07476	0.00431	0.00732	0.00686	0.29574
Error Re*GR*Tret	20	708.30	7.7889	58.133	0.5687	105.33	0.01545	0.00599	0.01338	0.00352	0.56764
Total	35										
F (GR)	--	0.53	0.29	64.00	38.87	55.71	108.85	0.06	0.03	0.76	5.31
F(Tret)	--	5.53	1.94	6.87	4.68	4.57	31.64	4.67	1.17	20.51	2.89
F(InT)	--	2.61	1.16	1.04	1.54	0.90	4.84	0.72	0.55	1.95	0.52
Grand Mean	--	39.768	16.500	26.000	18.939	148.62	0.7817	1.2725	7.2344	0.7122	6.5061
CV	-	14.96	16.91	29.33	3.98	6.91	15.90	6.08	1.60	8.33	11.58

Zapata and Zahara (2002) reported that crude rock phosphate is the cheap source of phosphate but the problem is related to its solubility. Farooq et al. (2018) found that combine use of rock phosphate with FYM, effective microbes and humic did not show increase in extractable AB – DTPA phosphorus and considered it as the influence of sorption, immobilization, dissolution of phosphorus.

The mean square and Analysis of variance (ANOVA) for various growth, yield and soil parameters are presented in Table 4.

REFERENCES

Alam, M., Khan, M. A., Imtiaz, M., Khan, M. A., Naeem, M., Shah, S. A., Samiullah, Ahmad, S. H., & Khan, L. (2019). Indole-3-Acetic Acid Rescues Plant Growth and Yield of Salinity Stressed Tomato (Lycopersicon esculentum L.). *Gesunde Pflanzen*, *72*(1), 87–95. https://doi.org/10.1007/s10343-019-00489-z

Alhrout, H. H., Akash, M. W., & Hejazin, R. K. (2018). Effect of farm yard manure and NPK on the yield and some growth components of tomato (Lycopersicum esculentum). *Research on Crops*, *19*(4), 655-658. https://doi.org/10.31830/2348-7542.2018.0001.43

Ali, A., Sharif, M., Wahid, F., Zhang, Z., Shah, S. N., , R., Zaheer, S., Khan, F., & Rehman, F. (2014). Effect of composted rock phosphate with organic materials on yield and phosphorus uptake of Berseem and maize. *American Journal of Plant Sciences*, *05*(07), 975-984. https://doi.org/10.4236/ajps.2014.57110

Almagro, M., & Martínez-Mena, M. (2014). Litter decomposition rates of green manure as affected by soil erosion, transport and deposition processes, and the implications for the soil carbon balance of a rainfed olive grove under a dry Mediterranean climate. *Agriculture, Ecosystems & Environment*, *196*, 167–177. https://doi.org/10.1016/j.agee.2014.06.027

Almeida, R. F., Queiroz, I. D. S., Mikhael, J. E. R., Oliveira, R. C., & Borges, E. N. (2019). Enriched animal manure as a source of phosphorus in sustainable

agriculture. *International Journal of Recycling of Organic Waste in Agriculture*, *8*(S1), 203–210. https://doi.org/10.1007/s40093-019-00291-x

Babatunde, K. M., Shittu, K. A., Adekanmbi, O. A., & Adesina, A. (2019). Effects of individual and combined application of organic plus NPK (15: 15: 15) fertilizer on the growth parameters of tomato (Lycopersicon esculentum Mill). *Journal of Agriculture and Horticulture Research*, *2*(1), 1-5.

Bakayoko, S., Soro, D., Nindjin, C., Thi, D., Tschannen, A., Girardin, O., & Assa, A. (2009). Effects of cattle and poultry manures on organic matter content and adsorption complex of a sandy soil under cassava cultivation (Manihot esculenta Crantz.). *African Journal of Environmental Science and Technology*, *3*(8), 190–197. https://doi.org/10.5897/ajest09.072

Baninasab, B., & Mobli, M. (2002). Effects of auxins and application methods on root regeneration of*Pistacia mutica*seedlings. *The Journal of Horticultural Science and Biotechnology*, *77*(3), 264–267. https://doi.org/10.1080/14620316.2002.11511490

Batlang, U. (2008). Benzyladenine plus Gibberellins (GA4+7) Increase Fruit Size and Yield in Greenhouse-Grown Hot Pepper (Capsicum annuum L.). *Journal of Biological Sciences*, *8*(3), 659–662. https://doi.org/10.3923/jbs.2008.659.662

Choudhury, S., Islam, N., Sarkar, M. D., & Ali, M. A. (2013). Growth and yield of summer tomato as influenced by plant growth regulators. *International journal of sustainable Agriculture*, *5*(1), 25-28. https://doi.org/10.5829/idosi.ijsa.2013.05.01.317

Cole, C., Williams, J., Shaffer, M., & Hanson, J. (2015). Nutrient and organic matter dynamics as components of agricultural production systems models. *SSSA Special Publications*, 147-166. https://doi.org/10.2136/sssaspecpub19.c9

Cordell, D., & Neset, T.-S. .S. (2014). Phosphorus vulnerability: A qualitative framework for assessing the vulnerability of national and regional food systems to the multi-dimensional stressors of phosphorus scarcity. *Global Environmental Change*, *24*, 108–122. https://doi.org/10.1016/j.gloenvcha.2013.11.005

Egamberdieva, D. (2009). Alleviation of salt stress by plant growth regulators and IAA producing bacteria in wheat. *Acta Physiologiae Plantarum*, *31*(4), 861–864. https://doi.org/10.1007/s11738-009-0297-0

Han, S. H., An, J. Y., Hwang, J., Kim, S. B., & Park, B. B. (2016). The effects of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (*Liriodendron tulipifera*Lin.) in a nursery system. *Forest Science and Technology*, *12*(3), 137-143. https://doi.org/10.1080/21580103.2015.1135827

Horta, C., Roboredo, M., Carneiro, J. P., Duarte, A. C., Torrent, J., & Sharpley, A. (2017). Organic amendments as a source of phosphorus: agronomic and environmental impact of different animal manures applied to an acid soil. *Archives of Agronomy and Soil Science*, *64*(2), 257–271. https://doi.org/10.1080/03650340.2017.1346372

Hye, M. A., Haque, M. S., & Karim, M. A. (2002). Influence of Growth Regulators and Their Time of Application on Yield of Onion. *Pakistan Journal of Biological Sciences*, *5*(10), 1021–1023. https://doi.org/10.3923/pjbs.2002.1021.1023

Ibrahim, M., Khan, Q.U., Khan, M. J., Ali, I., Rashid, M.M., Latif, A., Riaz, M. & Saleemullah, (2020). Effect of Potassium Fertilizer Integrated with Humic Acid and Cattle Manure on Tomato attributes and soil properties. *Journal of Pure and Applied. Agriculture*. 5(1):54-61. https://ojs.aiou.edu.pk/index.php/jpaa/article/view/1086

Khan, Q. U., Ahmad, R., Jamil, M., Sayal, O., Latif, A., Khakwani, A., Khan, G.,

Hashim, M. M., Mamoon-ur, M., & Parvez, M. (2013). Assessment of Various Growth, Yield and Nutritional Parameters of Tomatoes as Affected by Farmyard Manure Fortified with Potassium Fertilizer. *Pakistan Journal of Nutrition*, *12*(12), 1066–1069. https://doi.org/10.3923/pjn.2013.1066.1069

Mclean, E. O. (2015). Soil pH and Lime Requirement. *Agronomy Monographs*, 199–224. https://doi.org/10.2134/agronmonogr9.2.2ed.c12

Naz, M., Khan, Q. U., Khan, M. J., Sayal, O. U., Afridi, A., & Sayal, A. U. (2018). Impact of Foliar NPK and NAA Blended with Organic Material on Tomato Yield Attributes and Properties of Soil. *Pakistan Journal of Agricultural Research*, *31*(4). https://doi.org/10.17582/journal.pjar/2018/31.4.323.331

Nelson, D. W., & Sommers, L. E. (2015). Total Carbon, Organic Carbon, and Organic Matter. *Agronomy Monographs*, 539–579. https://doi.org/10.2134/agronmonogr9.2.2ed.c29

Ogundare, S. K., Babalola, T. S., Hinmikaiye, A. S., & Oloniruha, J. A. (2015). Growth and fruit yield of tomato as influenced by combined use of organic and inorganic fertilizer in Kabba, Nigeria. *European Journal of Agriculture and Forestry Research*, *3*(3), 48-56.

Olsen, S. R., & Watanabe, F. S. (1957). A method to determine a phosphorus adsorption maximum of soils as measured by the Langmuir Isotherm1. *Soil Science Society of America Journal*, *21*(2), 144. https://doi.org/10.2136/sssaj1957.03615995002100020004x

Overvoorde, P., Fukaki, H., & Beeckman, T. (2010). Auxin Control of Root Development. *Cold Spring Harbor Perspectives in Biology*, *2*(6), a001537–a001537. https://doi.org/10.1101/cshperspect.a001537

Pargi, S. C., Lal, E., Singh, N., & Biswas, T. K. (2014). Effect of naphthalene acetic acid on biochemical parameters, growth and yield of tomato (Lycopersicon esculentum mill.). *IOSR Journal of Agriculture and Veterinary Science*, *7*(7), 16-18. https://doi.org/10.9790/2380-07731618

Rahman, M., Nahar, M., Sahariar, M., & Karim, M. (2015). Plant growth regulators promote growth and yield of summer tomato (lycopersicone sculentum Mill.). *Progressive Agriculture*, *26*(1), 32–37. https://doi.org/10.3329/pa.v26i1.24512

Saha, K., Kabir, M. Y., Mondal, C., & Mannan, M. A. (2019). Growth and yield of tomato as affected by organic and inorganic fertilizers. *Journal of the Bangladesh Agricultural University*, *17*(4), 500–506. https://doi.org/10.3329/jbau.v17i4.44618

Serrani, J. C., Fos, M., Atarés, A., & García-Martínez, J. L. (2007). Effect of gibberellin and auxin on parthenocarpic fruit growth induction in the CV Micro-Tom of tomato. *Journal of Plant Growth Regulation*, *26*(3), 211-221. https://doi.org/10.1007/s00344-007-9014-7

Shahab, S., Ahmed, N., & Khan, N. S. (2009). Indole acetic acid production and enhanced plant growth promotion by indigenous PSBs. *African Journal of Agricultural Research*, *4*(11), 1312-1316.

Shakir, M. S. F. (2018). Investigating the release of phosphorus from rock phosphate pretreated with humic acid, farm yard manure and effective microbes. *International Journal of Biosciences*, *13*(06), 36-42.

Singh, N, J., Athokpam, H, S., Devi, K. N., Chongtham, N., Singh, N.B., Sharma, P.T. & Dayananda, S. (2015) Effect of farmyard manure and press mud on fertility status of alkaline soil under maize-wheat cropping sequence. *African Journal of Agricultural Research*, 10, 2421–2431. https://doi.org/10.5897/AJAR2013.8233

Steel, R.G.D., Torrie, J.H. & Dickey, D.A. (1997). *Principles and Procedures of Statistics: A Biometrical Approach*, 3rd edn. McGraw-Hill: New York, USA.

Tonfack, L., Brice, B., Mbouapouognigni, E., & Paul, V. (2009). Open Archive TOULOUSE Archive Ouverte (OATAO). *Fruits*, *64*, 167–177. https://doi.org/10.1051/fruits/2009012

Uddain, J., Hossain, K. A., Mostafa, M. G., & Rahman, M. J. (2009). Effect of different plant growth regulators on growth and yield of tomato. *International Journal of Sustainable Agriculture*, *1*(3), 58-63.

Waheed, A., Hamid, F.S., Ahmad, H., Abbassi, F.M., Aslam, S.A., Shah, H., Ahmad, N., Naheed, Z., Ali, H. & Khan, N. (2015) Effect of indole butyric acid (IBA) on early root formation (Tomato "Sahil" hybrid) cuttings. *Journal of Materials and Environmental Science*, 6, 272–279. https://www.jmaterenvironsci.com/Document/vol6/vol6_N1/33-JMES-1311-2014-Waheed.pdf

Wang, X., Shen, J., & Liao, H. (2010). Acquisition or utilization, which is more critical for enhancing phosphorus efficiency in modern crops? *Plant Science*, *179*(4), 302–306. https://doi.org/10.1016/j.plantsci.2010.06.007

Wang, Y.-J., Hao, Y.-J., Zhang, Z.-G., Chen, T., Zhang, J.-S., & Chen, S.-Y. (2005). Isolation of trehalose-6-phosphate phosphatase gene from tobacco and its functional analysis in yeast cells. *Journal of Plant Physiology*, *162*(2), 215–223. https://doi.org/10.1016/j.jplph.2004.06.014

Yu, X., Liu, X., Zhu, T.-H., Liu, G.-H., & Mao, C. (2012). Co-inoculation with phosphate-solubilzing and nitrogen-fixing bacteria on solubilization of rock phosphate and their effect on growth promotion and nutrient uptake by walnut. *European Journal of Soil Biology*, *50*, 112–117. https://doi.org/10.1016/j.ejsobi.2012.01.004

Zapata, F., & Zaharah, A. R. (2002). Phosphorus availability from phosphate rock and sewage sludge as influenced by the addition of water soluble phosphate fertilizer. *Nutrient Cycling in Agroecosystems*, *63*(1), 43–48. https://doi.org/10.1023/a:1020518830129