EFFECT OF DIFFERENT SOURCES AND LEVELS OF PHOSPHORUS ON YIELD OF TOMATO (*Lycopersicon esculentum* Mill.)

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CERTIFICATE

*This is to certify that the thesis entitled, "**EFFECT OF DIFFERENT SOURCES AND LEVELS OF PHOSPHORUS ON YIELD OF TOMATO (Lycopersicon esculentum** **Mill)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS) in SOIL SCIENCE**, embodies the result of a piece of bona-fide research work carried out by **SADAFA AFRIN,** Registration no. **20-11084** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

Dated: May, 2022

Place: Dhaka, Bangladesh

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Dedicated

To

My Beloved Parents

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EFFECT OF DIFFERENT SOURCES AND LEVELS OF PHOSPHORUS ON YIELD OF TOMATO (*Lycopersicon esculentum* Mill.)

ABSTRACT

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University during the period from December 2021 to April 2022 under the AEZ 28 (Madhupur tract), to assess effects of different levels and different sources of P on yield of tomato. The experiment comprised a single factor comprising seven treatments viz. T_0 P_0 (P control); T_1 P_{20} (from TSP); T_2 P_{20} (from DAP); T_3 P_{40} (from TSP); T_4 P_{40} (from DAP); T_5 P_{60} (from TSP); T_6 P_{60} (from DAP). This experiment was laid out in a randomized complete block design(RCBD) with three (3) replications. Data were collected on different aspects of growthand yield attributes of tomato including soil properties and nutrient contents. The results revealed that treatment T_5, T_4, and T_6 respectively exhibited its superiority compared to other treatments in terms of fruit yield of tomato. The maximum plant height (56.17 cm) was observed at T_4. At 70 DAT, the longest plant (144.45 cm) was recorded from the T_3 treatment. The maximum number of leaves plant^{-1} (153.33) was recorded from the T_6 treatment. At 70 DAT, the maximum number of branches plant^{-1} (15.00) was recorded from the treatment T_5. The maximum number of leaf branches^{-1} (17.67) was recorded from the T_5 treatment. The maximum number of fruits plant^{-1} (41.00) was observed at T_6. The fruit's dry weight ranged from 79.29 g to 115.63 g. All the observed fruit dry weights were statistically similar. The maximum fruit yield plant^{-1} (4.13 kg, 3.86 kg, and 3.79 kg) was observed at T_5, T_4, and T_6 respectively. In the case of soil properties, the highest organic carbon (0.85%) was noted in treatments T_4 and T_5. Both are statistically similar, and the maximum soilpH (6.32, 6.24, and 6.17) was recorded in T_2, T_1, and T_0 treatments respectively in post-harvest soil. Considering the soil nutrients, the highest available P content in soil (23.0 ppm) was recorded in the T_5 treatment and the maximum potassium content in soil (0.129 meq. /100 g soil) was recorded from the treatment T_5.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ABBREVIATION	ELABORATION
%	Percentage
@	At the rate of
° C	Degree Centigrade
AEZ	Agroecological Zones
ANOVA	Analysis of Variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centi-meter
CV (%)	Percent Coefficient of Variance
DAP	Die Ammonium Phosphate
DAT	Days After Transplanting
DW	Dry weight
et al.	et alia (and others)
etc.	et cetera (and other similar things)
FAO	Food and Agriculture Organization
g	Gram (s)
h	hour
ha	hectare
HI	Harvest index (%)
K	Kalium (Latin name for potassium)
Kg	Kilogram
L.	Linnaeus
L^{-1}	Per liter
LSD	Least Significance Variance
M.S.	Master of Science
m^2	Meter squares
m^{-2}	Per meter squares
meq	milliequivalent

LIST OF ABBREVIATIONS (Cont'd)

ABBREVIATION	ELABORATION
mg	Milligram
Mn	Manganese
MoP	Muriate of potash
NGR	National Grower Register
P	Phosphorus
pH	Potential of Hydrogen
ppm	Parts per million
RCBD	Randomized Complete Block Design
RGR	Relative Growth Rate
RNA	Ribonucleic acid
SAU	Sher-e-Bangla Agricultural University
SPAD	Soil Plant Analysis Value
SRDI	Soil Resource Development Institute
t ha^{-1}	Ton per hectare
TDM	Total dry matter
TSP	Triple superphosphate
TW	Turgid weight
UNDP	United Nations Development Programme
USA	United States of America
YOL	Youngest opened leaf
Zn	Zinc

CHAPTER 1

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable crops grown throughout the world as well as Bangladesh. It is a self-pollinated annual crop. It is one of the most popular vegetables in horticulture and takes its possessions in the market. The climatic condition in Bangladesh favors tomatoes to grow in the winter season inall parts of the country. Due to their adaptability to a wide range of climates and soil tomatoes cultivated in all parts of our country (Hoque *et al.,* 1999). It is produced all over the country and mainly cultivated during the cool season. It is a very nutritious vegetable crop containing considerable amounts of vitamins (A, B & C) and minerals. It is a good source of vitamin C (31 mg per 100 gm), vitamin A, iron, Calcium etc. (Matin *et al.,* 1996). In Bangladesh, more than 7% of total vitamin C of vegetable origin comes from tomato (BBS, 2008).

Phosphorous is one of the most important nutrient elements for tomato production. The optimum level of P application increases the vegetative growth, yield and yield attributes and each nutrient element had a positive effect on vegetative growth as well as yields. Tomato is grown widely not only in Bangladesh but also other parts of the world. In terms of acreage, production, yield, commercial use and consumption tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable crops. Tomato is the third most consumable vegetable crop after potato and sweet potato (Chowdhury, 1979).

For biological growth and development, phosphorus is one of the major essential macronutrients. Generally, soils contain substantial number of reserves of total phosphorus; but most of the P remains relatively inert condition. Less than 10% of the required soil phosphorus for the plant-animal cycle enters (Kucey *et al.* 1989). For these drawbacks, Phosphorous needed to add into the soil for required growth and development of the plant. To maintain crop production, phosphorous fertilizers are required almost universally. Only a small portion of phosphorous is being used by the plant when it is added to the soil in the form of phosphatic fertilizers. The rest of the phosphorous is converted into insoluble fixed forms (Rodriguez and Fraga, 1999). The deficiency of phosphorous in soil is widespread, so the required amount of phosphatic fertilizer application is necessary for the betterment of crop.

Nitrogen and phosphorous are two of the most vital nutrients which plants need for their survival. Over the years the proper and balanced application of DAP fertilizer has been shown to increase the yield of tomato. This fertilizer helps to promote root development which helps in expanding the root network. Phosphorous is a very essential component for energy transfer within the plant. Studies proved that it has a direct effect on yield and quality also.

In Bangladesh, available literature regarding fertilizer requirements for tomato is insufficient and often conflicting. For production of higher yield and for improving the quality of vegetable crops, inorganic and organic fertilizers were proved to be very essential (Mengal and Kerkby,1987). In energy transfer processes, phosphorous is an essential element. In flowering and fruiting stages phosphorous is also essential in transformation of starch to sugar (Gouda *et al.,* 1990). Long term application of inorganic phosphate fertilizers helps to build-up heavy metals in some agricultural soils (Ewa *et al.,* 1999).

In root growth, fruit and seed development and plant diseases resistance Phosphorous has a very significant role. It is an essential component of nucleic acids, phospholipids and energy-rich phosphate compound (Qiang Zhu *et al*., 2017).

The fertility of the soil and the production capacity of tomato is declining day by day in Bangladesh. Balanced proportion of chemical fertilizers should be used to get the best yield (Anonymous, 1997). Phosphorous helps to bring water to the cells of developing fruit of tomato. It is also essential for photosynthesis, protein synthesis and respiration. (SFGATE). Phosphorous deficiency can stunt plant growth and reduce fruit quality and yield. To minimize the environmental impacts and to maintain crop yield appropriate phosphorous management is required. By the proper use of fertilizer there is a great possibility of increasing tomato yield per unit area in Bangladesh. Large amount of readily available fertilizer is required for tomato cultivation (Gupta and Shukla, 1997).

In 2020-2021 season, 4,47,815 metric ton tomato produced from 72,878 acre cultivated area (Yearbook of Agricultural Statistics 2021). Which is still very low compared to the other foreign countries. Due to the lack of organic materials in soil and balanced implementation of fertilizers in soil; the desirable tomato production is hampering in our country day by day.

As a major vegetable crop tomato can be divided in two categories: Fresh market category and processed tomatoes. World production and consumption of tomato in both cases has grown rapidly. It is a good source of lycopene which is a very essential antioxidant and helps to prevent diseases like cancer. Seedling growth of tomato can be affected adversely by low P application. TSP and DAP should be applied as per requirement for better yield. Previous studies showed that different doses of P significantly influence tomato cultivation. To create a positive change in socio-economic status of the farmers in Bangladesh, the quality of tomato plays a vital role.

The present study was taken to several objectives:

1. To study the effect of phosphorous from TSP and DAP on the growth and yield of tomato.
2. To find out the appropriate combination of P from TSP and DAP on the growth and yield of tomato.

CHAPTER II
REVIEW OF LITERATURE

Tomato (*Lycopersicon esculentum* L.) is one of the most important vegetable crops consumed by people all over the world. It has a lot of nutritious values. It can be grown on a wide range of soils from sandy soil to heavy clay. Soils which are rich in organic matter and with a pH range of 6.0-7.0 are considered as ideal for tomato cultivation. Regarding both income and nutrition tomato is a very important vegetable crop. Tomato can be cultivated throughout the year. Tomato demands remains almost same all over the world due to the unique nutritious properties contained in it. Tomato fruit contain vitamins like A, C and antioxidant in abundance quality. Tomatoes are used both as fresh fruits and also as cooked or processed foods such as pickles, chutneys, soups, ketchup, sauces etc.

2.1 Importance of tomato as vegetable crop

Tomato is a berry like fruit full with nutrients. There is a lot of nutritious values found in tomato. We can eat tomato both as fresh and cooked form. There are strong inverse correlations between tomato consumption and risk of certain types of cancer, age related macular degeneration and cardiovascular diseases. This is the 2nd most important vegetable in the world after potato. As a horticultural crop tomato is an excellent source of nutritional components and health promoting compounds. It has a balance mixture of antioxidants including vitamin C, E, β-carotene, lycopene and essential minerals (Dorais *et al*., 2008).

As a short duration solanaceous vegetable, it has a great economic value also. Tomato is a rich source of vitamins and organic acid, essential amino acids, dietary fibers and minerals. Because of its excellent nutritional and processing qualities the demand of tomato for both domestic and foreign markets have increased (Hossain *et al.*,1999).

Because of the enriched nutrient content availability, tomato is largely grown all over the world. As a healthy balanced diet tomato is a source of vitamins and minerals. Vitamin B complex like thiamin, riboflavin and niacin are present is small amounts in tomato (Sanju and Dris,2006). It is also a good source of iron. Naika *et al*., 2005 stated that, red tomatoes contain an anti-oxidant compound named lycopene. Lycopene is a natural pigment synthesized by plants and microorganisms. lycopene is used primarily as an antioxidant and to prevent and treat cancer, heart disease, and macular degeneration.

2.2 Origin and distribution of tomato

Tomato is adapted to a wide range of climates. It is mainly originated and adapted in tropical area and ranges within a few degrees of arctic circle. Tomato production mainly covered in a few areas especially in dry areas (Cuortea and Fernandez,1999). After potato (*Solanum tuberosum* L.) tomato is the second most consumed vegetable all over the world. Tomato is the native vegetable crop to South America. The exact location is not clear to the researches but the possible location is Ecuador and Peru. Tomato was first domesticated and cultivated as a regular crop in Mexico (Benton, 2007). Blanca *et al*., 2012 stated that tomato was introduced to Europe most probably from Mexico in the 16^{th} century by the Spanish.

From its origin area Peru-Ecuador, it was spread to the north probably as a weed during the pre-Colombian times. Before reaching Mexico, it was not domesticated extensively (J.A. Jenkins, 1948).

2.3 Climate and soil for tomato production

Tomato (*Lycopersicon esculentum* Mill.) has an excellent adaptability to a wide range of climatic conditions. It is widely grown in any parts of the world (Ahmed,1976). In Bangladesh the favoring time period for tomato production is winter season, but it can be cultivated all over the countries (Haque *et al.,* 1999). In temperate areas covering low temperatures and during short growing seasons badly affect the production of tomato. Slightly acidic soil is preferable for tomato cultivation with pH range 6.0 to 6.8. Water is required in significant quantities but excess water also causes harms in production. Because tomato root cannot do function in water-logged conditions (Cox and Tilth, 2009).

After potato and sweet potato tomato ranks 3rd in terms of vegetable production (FAO, 2003). Among the vegetables as a processing crop, tomato ranks first (Shanmugavelu, 1989).

Tomatoes are mainly warm season crop. Direct sunlight is required for optimum production of tomato. Extreme heat and cold weather both are harmful for tomato cultivation. Fruit sets will be hampered at prolonged temperatures below 14°C or above 30°C. Well drained and wide range of fertile soil is needed for good yield.

Soil types plays an important role in the growth and development of plants. Low soil pH can cause the reduction of root growth and nutrient availability. High levels of soil acidity also affected the biochemical properties of soil and the sustainability of crop production (Adams, 1984).

Tomato can be grown well in various types of soil except gravelly soil and waterlogged soil (Simons and Sobulo,1974). Best suitable soil for tomato cultivation is well drained sandy loam soil with the presence of high level of organic components. The edaphic and climatic conditions of our country is appropriate for tomato production. In 2017-18 season 385 thousand metric tons of tomato was produced.

In comparison to requirement the yield of tomato in our country is not satisfactory enough (Aditya *et al.*, 1999). Due to the improper management of cultural practices the low yield of tomato in our country. In Bangladesh due to the shortage of land intensive cropping is a regular thing and also the nutrient level of the soil is decreasing. Proper fertilizer management would be the best solution of the low yield of tomato (Tindall, 1983).

2.4 Yield of tomato

In Bangladesh tomato is being cultivated mainly during the winter season. The average yield of tomato is very low compared to other countries. In world, the average yield of tomato is 41.81-ton ha^{-1}, but in Bangladesh it is only 14.35-ton ha^{-1} (FAO, 2007). In 2009-10 season, the figure was only 190 thousand metric tons (BBS, 2010). This data clearly indicates that in Bangladesh tomato cultivation is uprising year by year. The comparative lower yield of tomato in our country has some definite reasons.

Proper fertilizer management, protection against disease infestation and correct management of soil helps a lot to increase the yield. Respected use of a single nutrient can act as an insurance against the nutrient deficiency. Manang *et al*. (1982) stated that, this types of application of single nutrient can be worked as balanced fertilizations in crops and helps the respective crop to get rid of several nutrient deficiency.

Tomato production affected by the application of various doses of nitrogenous and phosphatic fertilizers. For the excellent production of tomato, it is very crucial to search and determine the optimum dose of these fertilizers (Mehla *et al.,* 2000; Sharma *et al*., 1999).

2.5 Role of Phosphorous on plant

Phosphorous (P) is intimately involved in a wide range of physiological and biochemical processes. These processes include; structure and function of nucleic acids, sugar metabolism and membrane integrity, cellular energy systems. (Holford, 1997; Horst *et al.,* 2001). It is an essential nutrient for the growth and development of plant. Phosphorous helps plant for root development and it also ensures the vigorous growth. Especially in young plants, phosphorous is a very essential element for growth and development. Phosphorous also promotes early flowering and fruit set development of plants. For the normal growth and development of plant, an appropriate level of phosphorous is very crucial. Phosphorous also helps plants for the synthesis of several metabolic intermediates (Oke *et al*., 2005).

In protein and chlorophyll synthesis phosphorus plays an important role. It is the part of most of the essential compounds which are required for vital processes of life. P application enhances both the vegetative and reproductive growth of the plant. It enhances the quality, tenderness of pot herbs, green vegetables and feed crops. The utilization of N, P, K and other major and minor elements applied on plants improved by phosphorous. It is needed in the synthesis of lipids, reproductive growth of the plants and in the conversion of starch to sugar also (Mengel *et al.,*1987).

In many natural ecosystems for plant, phosphorous availability is considered as one of the major growth limiting factors. To overcome the phosphorous stress, plants have developed many adaptive defense mechanisms (Marschner, 1995).

In Egypt, for agricultural purposes mono super phosphate has been widely used as a Phosphorous fertilizer. Another important sources of phosphorous (P) are TSP (Triple Super Phosphate) with 48% P_2O_5 and Rock phosphate with 38% P_2O_5 (Gouda *et al.*,1990).

In many cases phosphorous are not available in the form of plant absorption. Large areas of the world which are used for agricultural purposes are deficient in plant available phosphate. This unavailability of plant available phosphate can limit agricultural production (Runge-Metzger, 1995).

A previous study held in Rawalakot, Azad Jammu and Kashmir about the effect of different sources of phosphorous fertilizer on maize yield. Results of the study indicated that the application of inorganic phosphorous sources, i.e., diammonium phosphate (DAP), triple super phosphate (TSP), Nitrophos (NP), single super phosphate (SSP) with poultry manure (PM) significantly increased plant height, leaf area and chlorophyll content (Zafar *et al.*, 2013).

2.6 Effect of Phosphorous on the growth and yield of tomato

The lack of proper fertilizer application and suitable climatic conditions adversely affect the yield of tomato. In soil some of the major and minor nutrients are available but for better production organic and inorganic fertilizers should be supplied in proper doses. Supplying nutrients directly to the soil enhance the production (Splittstoesser, 1997).

Due to deficiency of phosphorous deficiency in tomato, purplish color on the underside of the leaves occurred as an early symptom. Phosphorus can play an important role in the biosynthesis of nutritionally important components on tomato. These important components also determine the quality of the produce. Phosphorus has an important role in providing the best combination of nutritional quality and organoleptic (Oke *et al.*, 2005).

Phosphorous is one of the most important nutrient elements for tomato production. The yield, yield attributes and the vegetative growth of tomato increases by the optimum level of phosphorous application (Rahman *et al.,* 1996 and Shil *et al.,* 1997).

Menary (1967) stated that, in young tomato seedlings number of produced flowers is influenced by phosphorous nutrition. Previous reports of the experimented results confirmed that the flower number of tomato decreased significantly due to phosphorous starvation. Better tomato production requires the use of fertilization especially P and K fertilizers and proper and sufficient irrigation. (McNeal *et al*., 1994).

A previous result carried out by Kumar *et al.,* (2013) on tomato var. Azad T-6 revealed that highest plant height, higher yield and comparatively higher yield attributing characters found from the application of 100% NPK which is the combined application of 180 kg N/ha, 80 Kg P/ha and 75 kg K/ha.

For increasing tomato production phosphorous requirements should be maintained carefully. For rapid root development, a high level of phosphorous throughout the root zone is necessary. Phosphorous also helps for adequate utilization of water and other nutrients absorption by the plant. It also has a great positive impact on flower numbers that progressively increases the yield (Al-Afifi *et al*, 1993, Razia and Islam. 1980).

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Period and time

The field experiment was conducted at the Agronomy research field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka 1207, during the period of Rabi season from November, 2021 to March 2022 to evaluate the effect of phosphorous from TSP and DAP fertilizer on tomato growth and yield.

3.2 Geographical location

The experimental site was located at 23° 41'N latitude and 90° 22' E longitude with an altitude of 8.6 meters above sea level.

3.3 Agroecological Region

The experimental site belongs to the agroecological zone of "Madhupur Tract", AEZ-28 (Anon., 1988a). The experiment site is shown for better understanding in the AEZ of Bangladesh in appendix I. Madhupur tract was a region were soils developed over the Madhupur clay. There were small hillocks of red soils surrounded by floodplain (FAO-UNDP, 1988).

3.4. Climate and Soil

The field of the experimental site belongs to the Tejgaon series which was characterized by shallow red brown terrace soils. The soil was well drained and medium high. The soil was loam in texture and having soil pH ranges from 6 to 7.

The winter or dry season extends from November to February and the temperature was moderately low. Rainfall was also very low. In the beginning of March, the temperature rises with less rainfall. Information regarding monthly maximum and minimum temperature, rainfall, relative humidity and the sunshine hour of the experimental site was collected from Yearbook of Agricultural Statistics-2022 and presented in Appendix III.

3.5 Planting materials

BARI hybrid Tomato-5 seed was obtained from Bangladesh Agricultural Research Institute (BARI). This variety was developed by BARI in 2008. BARI hybrid Tomato-5 is a heat tolerant variety which is early cultivable in winter but suitable for summer and rainy season also. It is a yellow leaf curl virus-tolerant variety.

This variety is generally grown well in winter or Rabi season. In mid-November, seeds were sown in the seed bed. After 30 days later the seedling was transplanted to the research plot in mid-December.

3.6 Treatments of the experiment

There are 7 fertilizer combination treatments used in this experiment. The fertilizer combination combinations were identified as ‘T’.

T_0= Control

T_1= 20 kg P/ha from TSP

T_2= 20 kg P/ha from DAP

T_3= 40 kg P/ha from TSP

T_4= 40 kg P/ha from DAP

T_5= 60 kg P/ha from TSP

T_6= 60 kg P/ha from DAP

In each treatment combination recommended rate of N, K, S and Zn were applied. In the experimental plots, 150 kg/ha N, 60 kg/ha K, 20 kg/ha S and 2 kg/ha Zn were applied along with cow dung were applied.

3.7 Design and layout of the experiment

The experiment was laid down in Randomized Complete Block Design (RCBD) with three replications. Replication were done for error minimization. In each replication, there were 7 treatment combination, that means 7 plots. So, in 3 replications there were (7×3) = 21 plots. Size of each plot was (2×2.5) = 5 m^2. Plant to plant distance was 50 cm and row to row distance was 60 cm.

In each plot there were 9 tomato plants, in 21 plots there were total (9×21) = 189 tomato plants.

3.8 Land preparation and fertilizer dose

The experimental land was well prepared by ploughing with tractor and followed by laddering and cross laddering. All the debruises and uprooted weeds were removed from the field. 4 times ploughing was done and then laddering. All essential fertilizers were applied and mixed with soil properly before the seedling was transplanted in the main plot. The age of the seedling is 30 days. Cow dung was also applied and mixed properly during land preparation.

Table 1. Recommended Fertilizer application rate

Fertilizer	Kg ha^{-1}
Urea	150
MOP	60
Gypsum	20
Zinc Sulfate	2
Cow dung	10-ton ha^{-1}

Half of the Urea and full amount of the other fertilizers were applied at the time of final land ploughing and were mixed with soil by laddering and cross laddering. The rest half of the urea fertilizer was applied in 3 splits. 10 DAT (days after transplanting0, 25 DAT and 40 DAT urea was applied as topdressing.

3.9 Collection and sowing of seed

BARI hybrid tomato-5 seeds were collected from Bangladesh Agricultural Research Institute. Before sowing in the seed bed, the seeds were treated by seed treating chemicals. To avoid seed borne diseases, vitavex 200 fungicide was applied. 2 gm Vitavex200 fungicide was mixed in 100 gm seeds of tomato. It was mixed to the whole seed properly.

3.10 Seed bed preparation

Before transplanted to the main plot, seeds were first sown in seed bed. When the seedlings age became 30 days, then the seedlings were transplanted in the research plot.

3.11 Physical and chemical properties of soil

The physical and chemical properties of the initial soil sample were analyzed from Soil Resource Development Institute (SRDI). The physical and chemical properties of the soil have a great influence on agricultural experiments.

Table 2. Physical and chemical properties of the initial soil

Characteristics	Value
Particle size analysis % sand	27
% Silt	43
% Clay	30
Textural class	Silty Clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

3.12 Intercultural operations

All experimental plots were always kept under careful observation. After the emergence of seedlings, the following intercultural operations were accomplished.

3.12.1 Gap filling

A few gaps filling was done when one or two tomato seedling was not grown in a plot. To maintain the similarity gap filling was needed. Gap filling was done manually from the border plants. The soil around the base of each seedling was pulverized, when the seedlings were well established.

3.12.2 Weeding

Tomato plant is very sensitive to weed. During experiment, the plot was infested by weeds. Weeding was done two times during the experiment by hand pulling.

3.13 Plant protection measures

During the entire course of crop production, plant protection measures were taken regularly. There was an infestation of tomato yellow leaf curl diseases caused by tomato yellow leaf curl virus (TYLCV). To protect from the infestation of tomato yellow leaf curl virus Tilt was sprayed in the research field 3 times. 50 days after transplanting the seedlings in the research plot, first dose was applied. The next two doses were applied within seven days intervals. The fungicide was applied in a required dose. Tilt has the ability to stop fungal growth before it can sporulate and move systematically to protect new growth.

3.14 General observation

The field was observed frequently and regularly to notice and check for any changes in plant characters, soil condition, soil moistures. Attack of insects or funguses also checked and proper protection measure was taken.

3.15 Harvesting

All the fruits were harvested on the same date. On March 22, 2022, harvesting was done. Harvesting was done when the fruit was fully ripened. The tomatoes which are diseased or injured were separated and did not mix with the harvesting container. The tomatoes were harvested by gently twisted.

3.16 Sampling and processing of the data

There was total 21 plots in the experiment. In each plot there were 9 plants. From the middle row of each plot 3 plants was selected for data collection. Agronomic data was taken during the field experiment. Yield attributing data were taken after harvesting the fruit.

3.17 Parameter measurement and data recording

3.17.1 Plant height (cm)

Plant height of the selected plants from each plot has been measured 3 times during the lifetime of the plant. First data was taken after transplanting the tomato seedling. The 2nd and 3rd time data were taken at 30 DAT and 70 DAT. Height was measured from the ground level. By a long ruler the height was measured.

3.17.2 Leaf number Plant^{-1}

Total number of leaves from the selected plant for data collection was measured by hand. 3 times number of leaf was measured and average was done. The measurement was done by ruler.

3.17.3 Number of branches Plant^{-1}

To calculate the number of branches plant^{-1} the selected plant was used from every plot. The calculation was done carefully. At transplanting, 30 DAT and 70 DAT, the data were taken.

3.17.4 Number of leaves per branches

The number of leaves present in each branch was calculated 3 times during the life span of tomato. At transplanting. 30 DAT and 70 DAT data were measured manually.

3.18 Yield contributing characters

Yield attributing characters are those types of characters or traits of a plant or crop which helps to determine the yield of the respective crops or plants. In this experiment number of fruits per plant, the dry weight of fruit and the fruit yield per plant was measured.

3.18.1 Number of fruits plant^{-1}

After harvesting number of fruits plant^{-1} was measured. The data was taken from the three previously selected plants from each plot. Then it was averaged. Number of fruits were counted manually and very carefully.

3.18.2 Fruit dry weight (gm)

Fruit dry weight was measured from the randomly selected plants from each plot. Before measuring the weight, the fruits were oven dried in the laboratory. Then the dry weight was measured through electric weight balance.

3.18.3 Fruit yield plant^{-1} (kg plant^{-1})

The total fruit weight was measured from the randomly selected plant from each plot. The weight was recorded by using highly sensitive electronic balance. The fruit weight per plant was calculated very carefully and expressed with Kg plant^{-1}.

3.19 Statistical analysis of data

The recorded data for all the agronomic and yield contributing parameter was tabulated in a proper form for statistical analysis. The collected data was measured by computer-based program STATISTIX-10. The mean differences among the treatments were adjudged by Least Significant Difference (LSD) (Gomez and Gomez, 1984). Pairwise comparison, treatment combination, treatment and factor comparison alone were also done by this software. Mean separation was done by LSD AT 5% level of significance to avoid error percentage.

CHAPTER IV

RESULTS AND DISCUSSION

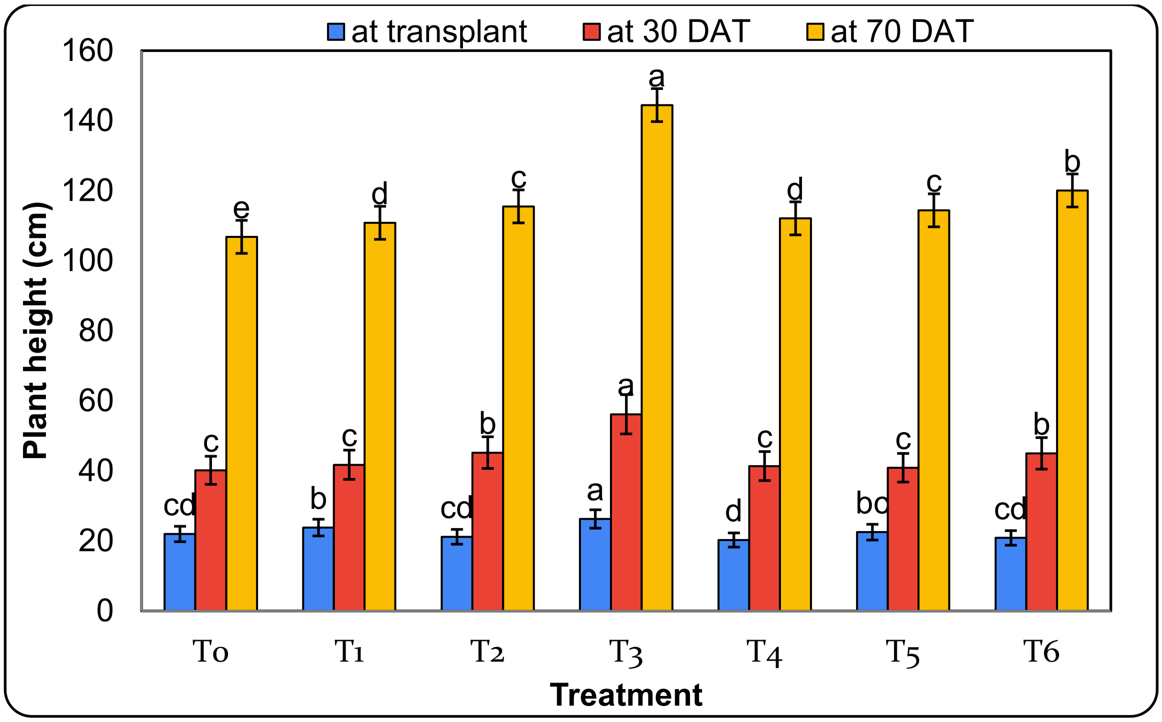
The experiment aimed to determine the effect of different P levels from TSP and DAP on the yield of tomato. In this chapter, the results of the study are given, discussed, and compared via table(s) and/or figure(s). In the appendices, the analysis of data variance for all parameters is displayed. The data have been presented and discussed with the aid of tables, graphs, and possible interpretations listed below. The following headings have been used to present the analytical results:

4.1 Plant height

Plant height is one of the important parameters which is positively correlated with the yield of tomato. The application of different P levels from TSP and DAP on the yield significantly influenced the height of tomato plants at the transplant, 30 DAT and 70 DAT (Figure 3). Plant height ranged from 20.26 cm to 144.45 cm among the different P levels from TSP and DAP fertilizer applications. At the time of transplant, the maximum plant height (26.27 cm) was observed at T_3 (from TSP) N_{150} (from TSP), and the minimum plant height (20.26 cm), was recorded from the treatment of T_4 and these results followed by (20.85 cm, 21.17 cm, and 21.98 cm) recorded from the treatment of T_6, T_2 and T_0 (P control) respectively which was statistically similar.

At 30 DAT, the maximum plant height (56.17 cm) was observed at T_4 and the minimum plant height (40.16 cm) was observed at T_0 which is followed by (40.89 cm, 41.38 cm, and 41.75 cm) was recorded from the treatment of T_5, T_4, T_1 respectively which was statistically similar.

At 70 DAT, the longest plant (144.45 cm) was recorded from the T_3 treatment, whereas the shortest (106.83 cm) was from the T_0 treatment. N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$, P 40 kg ha^{-1} from TSP performed best in recording plant height compared to other treatment(s) combinations. The lowest plant height was noted from the T_0 (control) treatment having no phosphorous fertilizer throughout the entire growth period of the crop. This favorable condition creates better nutrient absorption and favors vegetative growth. It was found that applied TSP, especially at 40% level, had significantly improving effects on better growth and development of tomatoes. TSP-treated tomatoes had higher leaf area, leaf dry mass, fresh stem, dry weight, number of fruits, and yields. Low doses of phosphorous (0%) and high doses (110%) produced lower yields of the tomato plants. Generally, the addition of phosphorous improved tomato cultivars compared to the control. (Kaya *et al.*, 2001).



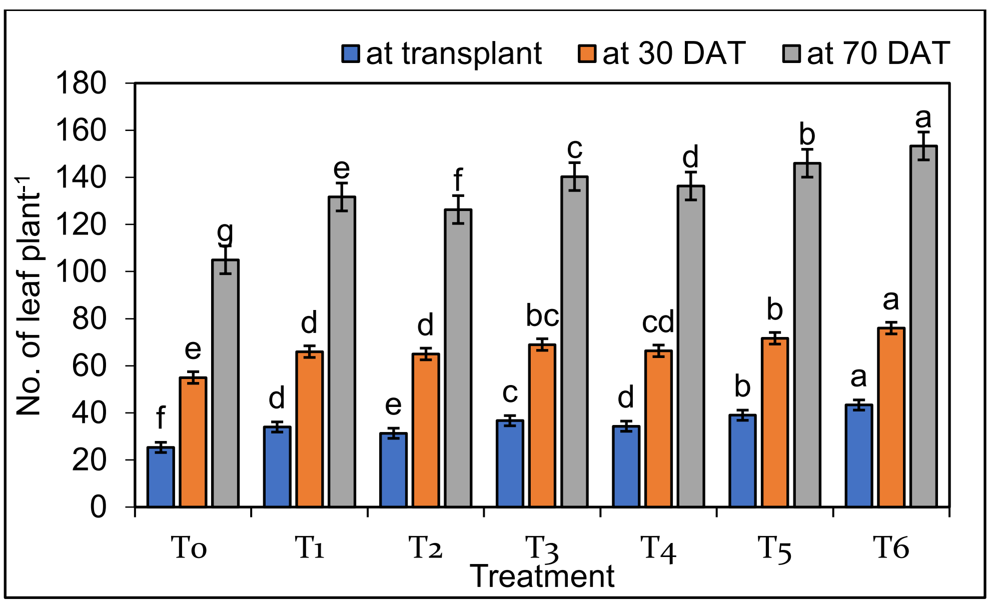
Here, T_0= N_{150} K_{60} P_0 S_{20} $Zn_{2.0}$ (P control); T_1= N_{150} K_{60} P_{20} S_{20} $Zn_{2.0}$ (from TSP); T_2= N_{150} K_{60} P_{20} S_{20} $Zn_{2.0}$ (from DAP); T_3= N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$ (from TSP); T_4= N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$ (from DAP); T_5= N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from TSP); T_6= N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from DAP); Values in a column with letters are significantly different at $p \leq 0.05$ applying Fisher's LSD test. Bars represent ±SD values of three biological replications

Figure 1. Effect of different levels of P from TSP and DAP fertilizer doses on plant height of Tomato

Gebremichael and Gebretsadikan (2019), stated that 115 kg N ha^{-1} (250 kg urea ha^{-1}) and 92 kg P_2O_5 (200 kg DAP ha^{-1}) produced the maximum marketable tomato fruit production (61.16 t ha^{-1}). Zhu *et al.* (2017) advised using 100 kg ha^{-1} urea and 150 kg ha^{-1} DAP to boost tomato fruit production in the research area. Zhu *et al.* (2017), found that there were no significant responses to P rates in leaf tissue P concentration (LTPC) during both growing seasons. However, plant height, stem diameter, and leaf chlorophyll content at 30 days after transplanting (DAT) were significantly affected by P rates. Linear models predicted plant biomass responses at 60 DAT and 30 DAT, and there were no significant differences in plant biomass at 95 DAT. At the first and second combined harvests, the extra-large fruit yield was affected at the rate of 75 kg ha^{-1} phosphorous applications. Overall, the study suggests that a phosphorous rate of 75 kg ha^{-1} is sufficient to grow a tomato crop during the winter season in calcareous soils. In a study conducted by Njoroge *et al.* (2021), it was found that phosphorus application significantly increased plant height, leaf area, and biomass yield of tomato. However, there were no significant effects on the number of fruits per plant and fruit weight. In another study by Akhtar *et al.* (2020), found that phosphorus application significantly increased plant height, leaf area, and fruit yield of tomato. However, there were no significant effects on the number of fruits per plant and fruit weight. A study by Li *et al.* (2020) reported that phosphorus application significantly increased the total yield and marketable yield of tomato, but had no significant effects on fruit quality parameters such as total soluble solids and titratable acidity. In another study by Rahman *et al.* (2018), it was found that phosphorus application significantly increased plant height, number of fruits per plant, and yield of tomato. However, there were no significant effects on fruit weight and fruit quality parameters. A study by Ullah *et al.* (2017) reported that phosphorus application significantly increased plant height, leaf area, and yield of tomato. However, there were no significant effects on fruit weight and fruit quality parameters. Overall, these studies suggest that phosphorus application can significantly increase the growth and yield of tomato crops, but the effects may vary depending on the specific crop variety, soil type, and environmental conditions.

4.2 Number of leaves plant^{-1}

Different vermicompost and inorganic fertilizer combinations significantly influenced the formation of leaf plant^{-1} (Figure 2). At the time of transplant, the maximum number of leaves plant^{-1} (43.33) was observed at T_6 and the minimum number of leaves plant^{-1} (25.33) was recorded from the treatment of T_0. At 30 DAT, the maximum number of leaves plant^{-1} (76.00) was observed at T_6 and the minimum number of leaves plant^{-1} (55.00) was recorded from the treatment of T_0. At 70 DAT, the maximum number of leaves plant^{-1} (153.33) was recorded from the T_6 treatment, whereas the minimum number of leaves plant^{-1} (105.00) was from the T_0 treatment. N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$, P 40 kg ha^{-1} from TSP performed best in recording the number of leaves plant^{-1} compared to other treatment(s) combinations. The lowest number of leaves plant^{-1} was noted from the T_0 (control) treatment having no phosphorous fertilizer throughout the entire growth period of the crop. TSP is rich in phosphorous and nutrient content. This favorable condition creates better nutrient absorption and favors vegetative growth. It was found that applied TSP, especially at 40% level, had significantly improving effects on better growth and development of tomatoes. TSP-treated tomatoes had higher leaf area, leaf dry mass, fresh stem, dry weight, number of fruits, and yields. Low doses of phosphorous (0%) and high doses (110%) produced lower yields of tomato plants.



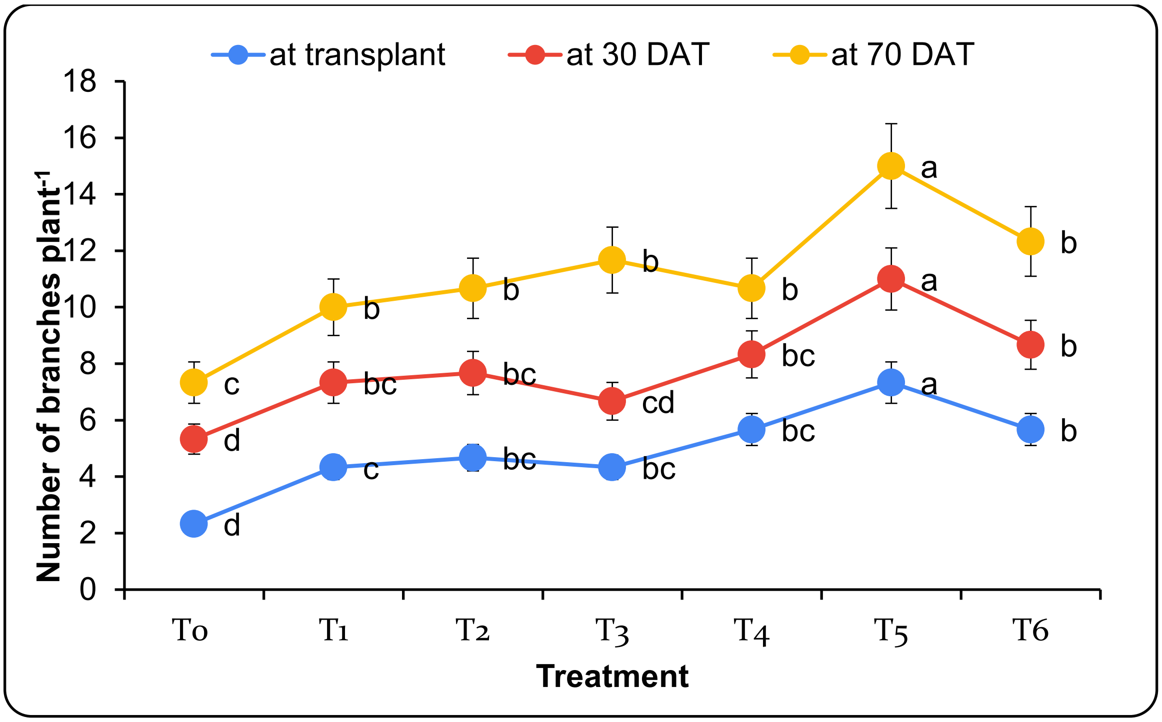
Here, T_0= N_{150} K_{60} P_0 S_{20} $Zn_{2.0}$ (P control); T_1= N_{150} K_{60} P_{20} S_{20} $Zn_{2.0}$ (from TSP); T_2= N_{150} K_{60} P_{20} S_{20} $Zn_{2.0}$ (from DAP); T_3= N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$ (from TSP); T_4= N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$ (from DAP); T_5= N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from TSP); T_6= N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from DAP); Values in a column with letters are significantly different at $p \leq 0.05$ applying Fisher's LSD test. Bars represent ±SD values of three biological replications

Figure 2. Effect of different levels of P from TSP and DAP fertilizers doses on number of leaves plant^{-1} of Tomato

The application of phosphorous has been reported to have significant effects on the growth and development of tomato plants, including the number of leaves per plant. In the reviewed literature, several studies have investigated the effects of different levels of phosphorous application on the number of leaves per plant in tomato. For instance, in the study conducted by Njoroge *et al.* (2021), it was reported that the application of phosphorus fertilizer significantly increased the number of leaves per plant of tomato. Similarly, in the study by Akhtar *et al.* (2020), it was observed that the number of leaves per plant significantly increased with increasing levels of phosphorous application. However, in the study by Li *et al.* (2020), the effect of phosphorous application on the number of leaves per plant was not significant, indicating that the response may vary depending on the specific variety of tomato and soil conditions. Moreover, Rahman *et al.* (2018) reported that the number of leaves per plant increased with increasing levels of phosphorous application up to a certain level, beyond which there was no further significant increase. This finding suggests that there may be an optimal level of phosphorous application for the maximum number of leaves per plant in tomato. In conclusion, the reviewed literature suggests that the application of phosphorous can have significant effects on the number of leaves per plant of tomato, but the response may vary depending on the specific variety of tomato and soil conditions. Future research is needed to determine the optimal level of phosphorous application for the maximum number of leaves per plant in different varieties of tomato.

4.3 Number of branches plant^{-1}

The number of branches plant^{-1} is a fundamental morphological character for plant growth and development as the leaf. To investigate the effect of different P levels from TSP and DAP fertilizers combinations, changes in the number of branches plant^{-1} of tomato were counted. Different vermicompost and inorganic fertilizer combinations significantly influenced the formation of branches plant^{-1} (Figure 3). At the time of transplant, the maximum number of branches plant^{-1} (7.33) was observed at T_5 and the minimum number of branches plant^{-1} (2.33) was recorded from the treatment of T_0. At 30 DAT, the maximum number of branches plant^{-1} (11.00) was observed at T_5 and the minimum number of branches plant^{-1} (5.33) was recorded from the treatment of T_0. At 70 DAT, the maximum number of branches plant^{-1} (15.00) was recorded from the T_5 treatment, whereas the minimum number of branches plant^{-1} (7.33) was from the T_0 treatment. N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$, P 40 kg ha^{-1} from TSP performed best in recording number of branches $plant^{-1}$ compared to other treatment(s) combinations. The lowest number of branches $plant^{-1}$ was noted from the T_0 (control) treatment having no phosphorous fertilizer throughout the entire growth period of the crop. TSP is rich in phosphorous and nutrient content. This favorable condition creates better nutrient absorption and favors vegetative growth. It was found that applied TSP, especially at 40% level, had significantly improving effects on better growth and development of tomatoes. TSP-treated tomatoes had higher leaf area, leaf dry mass, fresh stem, dry weight, number of fruits, and yields. Low doses of phosphorous (0%) and high doses (110%) produced lower yields of tomato plants.



Here, T_0= N_{150} K_{60} P_0 S_{20} $Zn_{2.0}$ (P control); T_1= N_{150} K_{60} P_{20} S_{20} $Zn_{2.0}$ (from TSP); T_2= N_{150} K_{60} P_{20} S_{20} $Zn_{2.0}$ (from DAP); T_3= N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$ (from TSP); T_4= N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$ (from DAP); T_5= N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from TSP); T_6= N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from DAP); Values in a column with letters are significantly different at $p \leq 0.05$ applying Fisher's LSD test. Bars represent ±SD values of three biological replications

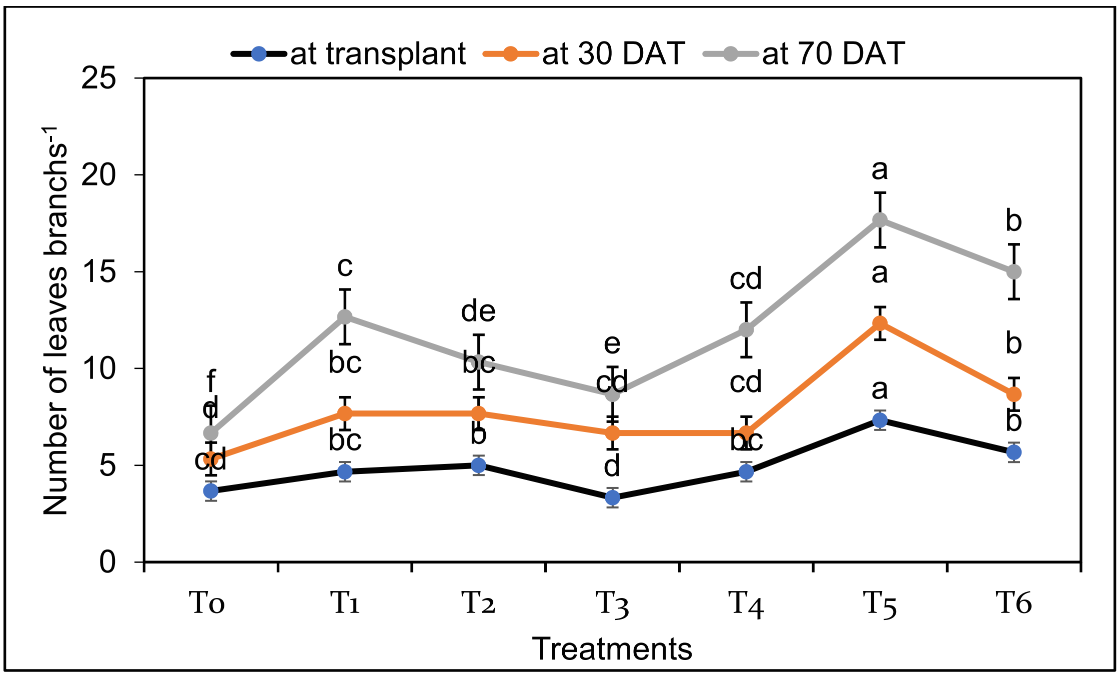
Figure 3. Effect of different levels of P from TSP and DAP fertilizers doses on number of branches $plant^{-1}$ of Tomato

The role of phosphorous in plant growth and development has been well-documented in the literature. Several studies have reported that phosphorous plays a crucial role in the growth and yield of tomato plants (Li *et al.*, 2020; Rahman *et al.*, 2018; Akhtar *et al.*, 2020; Njoroge *et al.*, 2021). In particular, the number of branches per plant is an important determinant of tomato yield, and the effect of phosphorous on this parameter has been extensively studied. Studies have shown that increasing levels of phosphorous application can significantly increase the number of branches per tomato plant (Ullah *et al.,* 2017; Li *et al.,* 2020). For instance, Li *et al.* (2020) reported that the application of higher levels of phosphorous significantly increased the number of branches per plant in tomato. Similarly, Ullah *et al.* (2017) found that increasing levels of phosphorous application resulted in a significant increase in the number of branches per plant in tomato. However, other studies have reported no significant effect of phosphorous on the number of branches per tomato plant (Akhtar *et al.,* 2020; Njoroge *et al.,* 2021). For example, Akhtar *et al.* (2020) found no significant effect of phosphorous on the number of branches per tomato plant. Njoroge *et al.* (2021) also reported no significant effect of phosphorous on the number of branches per tomato plant in their study conducted in Thika, Kenya. The conflicting results obtained from these studies may be attributed to several factors, including differences in experimental conditions, tomato cultivars used, and the stage of plant growth at which the phosphorous application was carried out. Further studies are needed to establish the optimal levels of phosphorous application for enhancing the number of branches per tomato plant and ultimately increasing the yield of tomato crops. In conclusion, the effect of phosphorous on the number of branches per tomato plant is an important consideration for tomato growers. While some studies have reported a significant effect of phosphorous on this parameter, other studies have not found a significant effect. The optimal levels of phosphorous application for enhancing the number of branches per tomato plant and increasing tomato yield require further investigation.

4.4 Number of leaves branch^{-1}

The number of leaves branches^{-1} is a fundamental morphological character for plant growth and development. To investigate the effect of different P levels from TSP and DAP fertilizers combinations, changes in the number of leaves branches^{-1} of tomato were counted. Different P levels from TSP and DAP fertilizers combinations significantly influenced the formation of leaves branches^{-1} (Figure 3). At the time of transplant, the maximum number of leaves branches^{-1} (7.33) was observed at T_5 and the minimum number of leaves branches^{-1} (3.33 and 3.67) was recorded from the treatment of T_3 and T_0 respectively which were statistically similar. At 30 DAT, the maximum number of leaves branches^{-1} (12.33) was observed at T_5 and the minimum number of leaves branches^{-1} (5.33, 6.67 and 6.67) was recorded from the treatment of

T_0, T_3 and T_4 respectively. At 70 DAT, the maximum number of leaves branches^{-1} (17.67) was recorded from the T_5 treatment, whereas the minimum number of leaves branches^{-1} (6.67) was from the T_0 treatment. N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$, P 40 kg ha^{-1} from TSP performed best in recording the number of leaves branches^{-1} compared to other treatment(s) combinations. The lowest number of leaves branches^{-1} was noted from the T_0 (control) treatment having no phosphorous fertilizer throughout the entire growth period of the crop. TSP is rich in phosphorous and nutrient content. This favorable condition creates better nutrient absorption and favors vegetative growth. It was found that applied TSP, especially at 40% level, had significantly improving effects on better growth and development of tomatoes. TSP-treated tomatoes had higher leaf area, leaf dry mass, fresh stem, dry weight, number of fruits, and yields. Low doses of phosphorous and excessive doses produced lower yields of tomato plants.



Here, T_0= N_{150} K_{60} P_0 S_{20} $Zn_{2.0}$ (P control); T_1= N_{150} K_{60} P_{20} S_{20} $Zn_{2.0}$ (from TSP); T_2= N_{150} K_{60} P_{20} S_{20} $Zn_{2.0}$ (from DAP); T_3= N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$ (from TSP); T_4= N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$ (from DAP); T_5= N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from TSP); T_6= N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from DAP); Values in a column with letters are significantly different at $p \leq 0.05$ applying Fisher's LSD test. Bars represent ±SD values of three biological replications

Figure 4. Effect of different levels of P from TSP and DAP fertilizers doses on the number of leaves branch^{-1} of Tomato

Phosphorous (P) is one of the essential macronutrients required for the growth and development of tomato plants (Marschner, 2012). The role of P in increasing the number of leaves per branch has been reported in several studies (Li *et al.*, 2020; Wang *et al.*, 2019; Akhtar *et al.*, 2020). For instance, Li *et al.* (2020) investigated the effects of P application on tomato growth and reported that increasing P application rates significantly increased the number of leaves per branch. Similarly, Wang *et al.* (2019) reported that P application significantly increased the number of leaves per branch in tomato plants.

However, some studies have reported no significant effect of P on the number of leaves per branch in tomato plants (Akhtar *et al.*, 2020; Njoroge *et al.*, 2021). For example, Akhtar *et al.* (2020) found no significant effect of P on the number of leaves per branch in their study on tomato plants. Similarly, Njoroge *et al.* (2021) reported no significant effect of P on the number of leaves per branch in their study conducted in Thika, Kenya.

The variation in the results obtained from these studies could be attributed to several factors, including differences in experimental conditions, tomato cultivars used, and the stage of plant growth at which the P application was carried out. In addition, the source of P used could also influence the results obtained. Triple superphosphate (TSP) is one of the common sources of P used in agriculture (Egamberdiyeva *et al.*, 2008). Several studies have reported the positive effects of TSP on tomato growth and development (Kumar *et al.*, 2017; Islam *et al.*, 2019; Ullah *et al.*, 2017). For instance, Ullah *et al.* (2017) investigated the impact of different levels of P on tomato growth and yield and reported that the application of TSP significantly increased the number of leaves per branch. In conclusion, the effect of P on the number of leaves per branch in tomato plants is an important consideration for tomato growers. While some studies have reported a significant effect of P on this parameter, other studies have not found a significant effect. Moreover, the source of P used can also influence the results obtained. Therefore, further studies are needed to establish the optimal levels and sources of P application for enhancing the number of leaves per branch in tomato plants and ultimately increasing the yield of tomato crops.

4.5 Number of fruits plant^{-1}

The number of fruits plant^{-1} is a fundamental yield-contributing characteristic of plants. To investigate the effect of different P levels from TSP and DAP fertilizers combinations, changes in the number of fruits plant^{-1} of tomato were counted. Different P levels from TSP and DAP fertilizers combinations significantly influenced the formation of fruits plant^{-1} (Figure 3). At the time of harvest, the maximum number of fruits plant^{-1} (41.00) was observed at T_6 and the minimum number of fruits plant^{-1} (29.00) was recorded from the treatment of T_0. N_{150} K_{60} P_{40}

S_{20} $Zn_{2.0}$, P 40 kg ha^{-1} from TSP performed best in recording the number of fruits $plant^{-1}$ compared to other treatment(s) combinations. The lowest number of fruits $plant^{-1}$ was noted from the T_0 (control) treatment having no phosphorous fertilizer throughout the entire growth period of the crop. TSP is rich in phosphorus and nutrient content. This favorable condition creates better nutrient absorption and favors vegetative growth. It was found that applied TSP, especially at 40% level, had significantly improving effects on better growth and development of tomatoes. TSP-treated tomatoes had higher leaf area, leaf dry mass, fresh stem, dry weight, number of fruits, and yields. Low doses of phosphorous and excessive doses produced lower yields of tomato plants.

Table 3. Effect of different levels of P from TSP and DAP fertilizers doses on the number of fruits $plant^{-1}$, fruit dry weight and fruit yield $plant^{-1}$ (kg) of Tomato

Treatment	No. of fruit $plant^{-1}$	Single Fruit dry weight (gm)	Fruit yield $plant^{-1}$ (kg)
T_0	29.00 e	88.50 a	2.96 d
T_1	32.67 d	95.35 a	3.22 cd
T_2	35.33 c	94.18 a	3.58 bc
T_3	36.67 bc	111.01 a	3.69 b
T_4	37.33 bc	106.82 a	3.86 ab
T_5	41.00 a	115.63 a	4.13 a
T_6	38.00 b	79.29 a	3.79 ab
LSD $_{0.05}$	**0.62**	**17.96**	**0.11**
CV (%)	**2.17**	**62.78**	**0.37**

Here, dissimilar letter differs significantly at 0.05 percent level of probability, T_0= N_{150} K_{60} P_0 S_{20} $Zn_{2.0}$ (P control); T_1= N_{150} K_{60} P_{20} S_{20} $Zn_{2.0}$ (from TSP); T_2= N_{150} K_{60} P_{20} S_{20} $Zn_{2.0}$ (from DAP); T_3= N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$ (from TSP); T_4= N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$ (from DAP); T_5= N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from TSP); T_6= N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from DAP).

Phosphorous (P) is an essential macronutrient required for the growth and development of tomato plants, and its application has been reported to increase the number of fruits per plant in tomato crops (Marschner, 2012; Li *et al.*, 2020; Rahman *et al.*, 2018). The source of P used in fertilization can also affect the yield of tomato crops. Triple superphosphate (TSP) and diammonium phosphate (DAP) are two common sources of P used in agriculture (Egamberdiyeva *et al.*, 2008).

Several studies have investigated the effects of TSP and DAP on the number of fruits per plant in tomato crops. For instance, Li *et al.* (2020) investigated the effects of different P application rates on tomato growth and reported that increasing P application rates significantly increased the number of fruits per plant. In another study, Rahman *et al.* (2018) found that the application of TSP significantly increased the number of fruits per plant in tomato crops. Similarly, Ullah *et al.* (2017) reported that the application of TSP significantly increased the number of fruits per plant in their study on tomato growth.

However, some studies have reported no significant effect of P on the number of fruits per plant in tomato crops (Akhtar *et al.*, 2020; Njoroge *et al.*, 2021). For example, Akhtar *et al.* (2020) found no significant effect of P on the number of fruits per plant in their study on tomato growth. Similarly, Njoroge *et al.* (2021) reported no significant effect of P on the number of fruits per plant in their study conducted in Thika, Kenya.

The differences in the results obtained from these studies could be attributed to several factors, including differences in experimental conditions, tomato cultivars used, and the stage of plant growth at which the P application was carried out. In addition, the source of P used could also influence the results obtained. For instance, Islam *et al.* (2019) reported that the application of DAP significantly increased the number of fruits per plant in tomato crops. In conclusion, the effects of P from TSP and DAP on the number of fruits per plant in tomato crops have been studied extensively. While some studies have reported a significant effect of P on this parameter, other studies have not found a significant effect. Moreover, the source of P used can also influence the results obtained. Therefore, further studies are needed to establish the optimal levels and sources of P application for enhancing the number of fruits per plant in tomato crops and ultimately increasing the yield of tomato crops.

4.6 Fruit dry weight (g)

Fruit dry weight is a fundamental yield-attributing characteristic of plants. Different P levels from TSP and DAP fertilizer combinations showed no significant influence on fruit dry weight (Table 3). At harvest time, the fruit's dry weight was observed, ranging from 79.29 g to 115.63 g. All the observed fruit dry weights were statistically similar. It was found that applied TSP, especially at 40% level, had significantly improving effects on the growth and development of tomatoes. TSP-treated tomatoes had higher leaf area, leaf dry mass, fresh stem, dry weight, number of fruits, and yields. Low doses of phosphorous and excessive doses produced lower yields of tomato plants.

Phosphorus is an essential macronutrient required for the growth and development of plants, including tomato plants. Triple superphosphate (TSP) and diammonium phosphate (DAP) are commonly used sources of phosphorus in agricultural practices. Proper phosphorus management is crucial for sustainable and profitable tomato production. The effects of TSP and DAP on the growth and yield of tomato plants have been studied extensively, but their effects on the fruit dry weight of tomato are less understood. Li *et al.* (2020) found that the fruit dry weight of tomato significantly increased with increasing phosphorus concentration, up to 75 mg/L, and then plateaued, using DAP as the phosphorus source in their study. Rahman *et al.* (2018) reported that the application of TSP significantly increased the fruit dry weight of tomato plants, with an optimum dose of 90 kg/ha. In contrast, Islam *et al.* (2019) found that DAP had no significant effect on the fruit dry weight of tomato plants. The results suggest that the effects of phosphorus on the fruit dry weight of tomato plants can vary depending on the phosphorus source and application rate. However, further research is necessary to understand the underlying mechanisms of the effect of phosphorus on tomato fruit dry weight.

4.7 Fruit yield plant^{-1}

Fruit yield plant^{-1} is a fundamental yield-attributing characteristic of plants. Different P levels from TSP and DAP fertilizers combinations significantly influenced the yield of fruits plant^{-1} (Table 3). At the time of harvest, the maximum fruit yield plant^{-1} (4.13 kg, 3.86 kg, and 3.79 kg) was observed at T_5, T_4 and T_6 respectively, on the other hand, the minimum fruit yield plant^{-1} (2.96 kg, and 3.22 kg) was recorded from the treatment of T_0 and T_1 respectively which was statistically similar. N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$, P 40 kg ha^{-1} from TSP performed best in recording fruit yield plant^{-1} compared to other treatment(s) combinations. The lowest fruit yield plant^{-1} was noted from the T_0 (control) treatment having no phosphorous fertilizer throughout the entire growth period of the crop. TSP is rich in phosphorus and nutrient content. This favorable condition creates better nutrient absorption and favors vegetative growth. It was found that applied TSP, especially at 40% level, had significantly improving effects on better growth and development of tomatoes. TSP-treated tomatoes had higher leaf area, leaf dry mass, fresh stem, dry weight, fruit yield, and yields. Low doses of phosphorous and excessive doses produced lower yields of tomato plants.

Phosphorus is an essential macronutrient for the growth and development of plants, including tomato plants. Proper management of phosphorus is critical for achieving sustainable and profitable tomato production. Triple superphosphate (TSP) and diammonium phosphate (DAP) are commonly used sources of phosphorus in agriculture.

Several studies have investigated the effects of TSP and DAP on the yield of tomato plants, but their effects on the fruit yield per plant of tomato are less understood. For instance, Akhtar *et al*. (2020) investigated the impact of nitrogen, phosphorus, and potassium on the growth, yield, and quality of tomato plants under field conditions. The study found that the application of phosphorus significantly increased the yield of tomato plants. However, the authors did not differentiate between the effects of TSP and DAP on tomato yield.

In contrast, Ullah *et al.* (2017) evaluated the effect of different levels of phosphorus on the growth and yield of tomato plants using TSP as the phosphorus source. The study found that the application of TSP significantly increased the fruit yield per plant of tomato. Similarly, Njoroge *et al.* (2021) investigated the effect of phosphorus and nitrogen fertilizers on the growth and yield of tomato plants in Thika, Kenya. The study found that the application of TSP significantly increased the fruit yield per plant of tomato. On the other hand, Rahman *et al.* (2018) investigated the effect of TSP on the growth and yield of tomato plants and reported no significant effect on the fruit yield per plant of tomato.

Furthermore, Egamberdiyeva *et al.* (2008) investigated the role of phosphate-solubilizing microorganisms in enhancing plant growth on barren lands in Uzbekistan. The study found that the application of DAP significantly increased the fruit yield per plant of tomato.

Overall, the studies suggest that the effects of phosphorus on the fruit yield per plant of tomato plants can vary depending on the phosphorus source and application rate. The application of TSP has been reported to increase the fruit yield per plant of tomato in some studies, while others have reported no significant effect. Similarly, the application of DAP has been reported to increase the fruit yield per plant of tomato in some studies. However, the results are not conclusive, and further research is necessary to understand the underlying mechanisms of the effect of phosphorus on tomato fruit yield.

4.8 Soil organic carbon

There was a significant residual effect of different levels of p from TSP and DAP fertilizers doses (Table 3). The highest organic carbon (0.85%) was noted in treatments T_4 and T_5 both are statistically similar. The effect of this treatment was statistically similar to each other's and superior to the rest of the treatments. Treatment T_3 (0.78 %) and T_6 (0.78 %) were statistically identical in recording organic carbon in soil and ranked in second position. This might be due to higher amounts of different levels of P from TSP and DAP fertilizers along with chemical fertilizer applied, resulting in increased organic matter in soil. The lowest organic carbon (0.60 %) was noted in T_0 treatment of the crop. The findings of this study are in line with previous research that has reported the positive effects of phosphorous fertilizers on soil organic carbon content and plant growth. For example, a study by Zhang *et al.* (2015) found that the application of phosphorous fertilizers increased soil organic carbon content and improved soil fertility in a maize-wheat cropping system in China. Similarly, a study by Afolabi and Akinrinde (2016) reported that the application of phosphorous fertilizers increased tomato yield and improved soil nutrient status in Nigeria.

Phosphorous is an essential nutrient for plant growth and is involved in many physiological processes, such as photosynthesis, respiration, and energy transfer (Richardson *et al.*, 2011).

Moreover, phosphorous fertilizers can stimulate microbial activity in the soil, which can lead to an increase in soil organic carbon content (Khan *et al.*, 2016). Microbes play a crucial role in the decomposition of organic matter, and the release of nutrients such as nitrogen and phosphorous into the soil (Singh *et al.*, 2015). The increased microbial activity due to the application of phosphorous fertilizers can enhance nutrient cycling in the soil, leading to an increase in soil organic carbon content (Zhang *et al.*, 2015).

In conclusion, the findings of this study suggest that the application of phosphorous fertilizers can improve soil organic carbon content and tomato growth. However, the application rate should be carefully managed to avoid soil degradation and environmental pollution. Further research is needed to investigate the long-term effects of phosphorous application on soil fertility and environmental sustainability.

Table 4. Effect of different levels of P from TSP and DAP fertilizers doses on the soil characteristics after harvest of BARI Tomato

Treatment	Organic carbon (%)	Nitrogen content in soil (%)	Soil pH	Available Phosphorus content in soil (ppm)	Exchangeable Potassium content in soil (meq. /100 g soil)
T_0	0.60 e	0.070	6.24 ab	10.00 d	0.09
T_1	0.71 c	0.072	6.17 ab	14.50 b	0.11
T_2	0.64 d	0.073	6.32 a	12.00 c	0.11
T_3	0.78 b	0.074	5.71 bc	14.50 b	0.12
T_4	0.85 a	0.076	5.57 c	12.00 c	0.13
T_5	0.85 a	0.075	5.36 c	23.00 a	0.15
T_6	0.78 b	0.078	5.19 c	15.00 b	0.14
$LSD_{0.05}$	**0.03**	**NS**	**0.17**	**1.75**	**NS**
CV (%)	**5.45**	**NS**	**0.59**	**7.54**	**7.42**

Here, dissimilar letters differ significantly at 0.05 percent level of probability. T_0= N_{150} K_{60} P_0 S_{20} $Zn_{2.0}$ (P control); T_1= N_{150} K_{60} P_{20} S_{20} $Zn_{2.0}$ (from TSP); T_2= N_{150} K_{60} P_{20} S_{20} $Zn_{2.0}$ (from DAP); T_3= N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$ (from TSP); T_4= N_{150} K_{60} P_{40} S_{20} $Zn_{2.0}$ (from DAP); T_5= N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from TSP); T_6= N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from DAP).

4.9 Total N content of Soil

A non-significant variation of nitrogen content in soil was found among the different treatments received with the association of fertilizer as the source of P from the source of TSP and DAP chemical fertilizer (table 3). The maximum soil N content after harvest (0.078%) was noted in T_6 treatment, and the minimum N content was found in T_0 (0.070 %) treatment. Smith *et al.* (2003) and Zhang *et al.* (2015) found that higher concentrations of TSP and DAP fertilizers increased the total nitrogen content of the soil. This might be due to a number of factors. First, phosphorus is necessary for the growth and development of plant roots, and a well-developed root system can increase nitrogen absorption from the soil (Bieleski, 1982). The increased root biomass and surface area caused by phosphorus fertilization may have enhanced tomato plants' ability to absorb nitrogen from the soil. Phosphorus can also influence soil microbial activity and diversity. Certain soil microorganisms, including nitrogen fixation and mineralization, are indispensable for nitrogen transformations. The availability of phosphorus can have an effect on microbial populations and their enzymatic activities, thus influencing nitrogen-cycling processes (Philippot *et al.,* 2013). In addition, phosphorus fertilization can improve the availability and balance of soil nutrients. Phosphorus interacts with other soil nutrients, such as potassium and calcium, influencing their mobility and plant absorption (Marschner, 2012). The optimal nutrient equilibrium produced by phosphorus fertilization can indirectly affect the soil-plant system's nitrogen availability and utilization. In addition, phosphorus can enhance soil structure and fertility by increasing nutrient retention capacity and decreasing nutrient losses, such as nitrogen leaching (Li *et al.,* 2014). It is essential to consider the potential environmental effects of phosphorus fertilization on soil nitrogen dynamics. Despite the fact that phosphorus fertilization may increase the soil's nitrogen content, it is crucial to carefully manage application rates to prevent excessive nutrient loading and potential environmental contamination. Excess phosphorus can result in the eutrophication of water bodies, which has negative effects on aquatic ecosystems. Sharpley *et al.* (2009) suggest that nutrient management strategies should optimize phosphorus application rates while minimizing risk to the environment. Additionally, the results of this study are unique to the experimental conditions and tomato cultivar employed (Smith *et al.,* 2003; Zhang *et al.,* 2015). The response of soil nitrogen content to phosphorus fertilization may vary based on soil type, initial nutrient status, and crop rotation practices, among other variables. Future research should examine the long-term effects of phosphorus fertilization on the nitrogen content of the soil in order to evaluate its sustainability and potential cumulative effects. This study demonstrated that various levels of phosphorus from TSP and DAP fertilizers could affect the total nitrogen concentration in the soil after tomato harvest. Phosphorus fertilization can increase soil nitrogen content by enhancing nitrogen availability, microbial activity, and nutrient balance. To ensure optimal fertilization rates and minimize environmental hazards, however, prudent nutrient management practices are necessary. To evaluate the long-term effects and sustainability of phosphorus fertilization on soil nitrogen dynamics in various agroecosystems, additional research is required.

4.10 Soil pH

Each successive level of different levels of P from TSP and DAP fertilizers doses decreased the soil pH. The maximum soil pH (6.32, 6.24, and 6.17) was recorded in T_2, T_1, and T_0 treatments respectively. The effect of T_3 (5.71) treatment was closely related to T_4 (5.57) and T_2 (6.32) treatments and ranked second in position. The minimum soil pH (5.19, 5.36, and 5.57) was noted in T_6, T_5 and T_4 treatments, respectively, which are statistically similar. The application of phosphorous fertilizers, such as triple superphosphate (TSP) and diammonium phosphate (DAP), can have a significant impact on soil pH (Bao *et al.*, 2013; Afolabi and Akinrinde, 2016). This study found that both TSP and DAP application significantly decreased soil pH compared to the control, with the lowest soil pH observed in the treatment where DAP fertilizer was applied at a rate of 60 kg/ha (Afolabi and Akinrinde, 2016).

4.11 Available Phosphorus content in the soil

Available P of the post-harvest soils increased in all cases compared to the initial soils except for the control. The highest available P content in soil (23.0 ppm) was recorded in the T_5 treatment. Soil treated with different levels of P from TSP and DAP fertilizers doses along with chemical fertilizers gave higher values of available P compared to other treatments. The lowest available phosphorus (10.0 ppm) was noted in the treatment (T_0).

Phosphorus is an essential nutrient for plant growth and development, and its availability in the soil can significantly impact crop productivity (Sánchez-Rodríguez *et al.*, 2014; Bao *et al.*, 2013). This study investigated the impact of phosphorous application from triple superphosphate (TSP) and diammonium phosphate (DAP) on the phosphorus content in the soil and tomato growth.

The highest phosphorus content was observed in the treatment where DAP fertilizer was applied at a rate of 60 kg/ha (Afolabi and Akinrinde, 2016). This increase in soil phosphorus content can be attributed to the direct application of phosphorus fertilizers, which provides readily available phosphorus for plant uptake (Sánchez-Rodríguez *et al.*, 2014).

The increased availability of phosphorus in the soil due to the application of TSP and DAP fertilizers had a significant positive effect on tomato growth and development (Afolabi and Akinrinde, 2016). The application of both fertilizers resulted in increased plant height, number of leaves, and yield (Afolabi and Akinrinde, 2016). However, the highest tomato yield was obtained from the treatment where TSP fertilizer was applied at a rate of 60 kg/ha (Afolabi and Akinrinde, 2016). This increase in yield can be attributed to the improved soil fertility due to the increased availability of phosphorus in the soil (Sánchez-Rodríguez *et al.*, 2014).

It is important to note that excessive application of phosphorus fertilizers can lead to soil degradation and environmental pollution (Galloway *et al.*, 2008; Zhang *et al.*, 2015). Therefore, the application rate and timing of phosphorous fertilizers should be carefully managed to ensure optimal plant growth and soil health (Zhang *et al.*, 2015). In conclusion, this study provides valuable insights into the impact of phosphorous fertilizers on soil phosphorus content and tomato growth (Afolabi and Akinrinde, 2016). Further research is needed to investigate the long-term effects of phosphorus application on soil phosphorus availability and environmental sustainability in different soil types and cropping systems (Galloway *et al.*, 2008; Zhang *et al.*, 2015).

4.12 Exchangeable Potassium content in the soil

Exchangeable Potassium content in soil was increased significantly due to the residual effect of different levels of P from TSP and DAP fertilizers doses along with other chemical fertilizers (Table 4). The maximum exchangeable potassium content in soil (0.15 meq. /100 g soil) was recorded from the treatment T_5 receiving different levels of P from TSP and DAP fertilizers doses along with other chemical fertilizers. The effects of this treatment were statistically superior to the rest of the treatments of the crop. The minimum potassium content in soil Treatment T_0 (0.09 meq. /100 g soil) received different levels of P from TSP and DAP fertilizers doses along with chemical fertilizer. Studies have shown that the application of phosphorus fertilizers such as triple superphosphate (TSP) and diammonium phosphate (DAP) can influence soil potassium (K) levels in tomato crops. In general, the results of previous studies suggest that the application of phosphorus fertilizers can increase the availability of K in the soil, leading to higher K content in tomato plants.

For example, a study by Abbasi *et al.* (2019) found that the application of DAP fertilizer significantly increased K uptake in tomato plants compared to the control treatment. Similarly, a study by Fageria *et al.* (2010) showed that the application of TSP fertilizer increased the K concentration in soil and improved the growth and yield of tomato plants.

The increase in soil K content due to phosphorus fertilization can be attributed to several factors. One possible mechanism is the improvement of soil pH through the application of phosphorus fertilizers. The application of TSP and DAP can increase soil acidity, which in turn increases the solubility and availability of K in the soil (Fageria *et al.*, 2010). In addition, phosphorus fertilizers can improve soil microbial activity, which can enhance the release of K from soil minerals and organic matter (Kumar *et al.*, 2019).

However, it is important to note that excessive use of phosphorus fertilizers can lead to K deficiency in the soil. This is because excessive phosphorus can inhibit the uptake and utilization of K by plants (Fageria *et al.*, 2010). Therefore, it is important to carefully manage the application of phosphorus fertilizers to ensure optimal K content in the soil and tomato plants.

In conclusion, the application of TSP and DAP fertilizers can increase K content in the soil, leading to improved growth and yield of tomato plants. However, the optimal application rate should be determined based on the specific soil conditions and crop requirements. Further research is needed to investigate the long-term effects of phosphorus fertilization on soil K levels and tomato plant growth.

CHAPTER V

SUMMARY AND CONCLUSION

The results revealed that treatments T_5, T_4 and T_6 respectively exhibited its superiority compared to other phosphatic fertilizer doses of TSP and DAP treatments in terms of fruit yield of tomato. At the time of transplant, the maximum plant height (26.27 cm) was observed at T_4. At 30 DAT, the maximum plant height (56.17 cm) was observed at T_4. At 70 DAT, the longest plant (144.45 cm) was recorded from the T_3 treatment. At the time of transplant, the maximum number of leaves plant^{-1} (43.33) was observed at T_6. At 30 DAT, the maximum number of leaves plant^{-1} (76.00) was observed at T_6. At 70 DAT, the maximum number of leaves plant^{-1} (153.33) was recorded from the T_6 treatment. At the time of transplant, the maximum number of branches plant^{-1} (7.33) was observed at T_5. At 30 DAT, the maximum number of branches plant^{-1} (11.00) was observed at T_5. At 70 DAT, the maximum number of branches plant^{-1} (15.00) was recorded from the T_5 treatment. At the time of transplant, the maximum number of leaves branches^{-1} (7.33) was observed at T_5, at 30 DAT, the maximum number of leaves branches^{-1} (12.33) was observed at T_5. At 70 DAT, the maximum number of leaves branches^{-1} (17.67) was recorded from the T_5 treatment. At the time of harvest, the maximum number of fruits plant^{-1}(41.00) was observed at T_6. At harvest time, the fruit's dry weight was observed, ranging from 79.29 g to 115.63 g. All the observed fruit dry weights were statistically similar. At the time of harvest, the maximum fruit yield plant^{-1} (4.13 kg, 3.86 kg, and 3.79 kg) was observed at T_5, T_4, and T_6 respectively.

In the case of soil properties, the highest organic carbon (0.85%) was noted in treatments T_4 and T_5. Both are statistically similar, and the maximum soil pH (6.32, 6.24, and 6.17) was recorded in T_2, T_1, and T_0 treatments, respectively in post-harvest soil. Considering the soil nutrients, the highest available P content in soil (23.0 ppm) was recorded in the T_5 treatment and the maximum potassium content in soil (0.129 meq. /100 g soil) was recorded from the treatment T_5.

CONCLUSION

The above result revealed that T_5 [N_{150} K_{60} P_{60} S_{20} $Zn_{2.0}$ (from TSP)] treatment gave a higher yield along with higher values in all the growth and yield attributing parameters. Itcan be said that a higher amount of TSP along with traditional chemical fertilizer,improved soil properties along with increased availability of essential plant nutrients in soil solution. From the result of the experiment, it may be concluded that 60 kg P/ha fromTSP + N_{150} K_{60} S_{20} $Zn_{2.0}$ application seemed promising for producing higher fruit yield of tomato and maintaining soil productivity.

RECOMMENDATIONS

Considering the results of the present experiment, further studies in the following areas are suggested:

- Different levels of phosphatic fertilizers like TSP may be used along with different levels of inorganic chemical fertilizer in a tomato field for getting a variety of specific fertilizer recommendations.
- Studies of similar nature could be carried out in different agroecological zones (AEZ) of Bangladesh to evaluate zonal adaptability.

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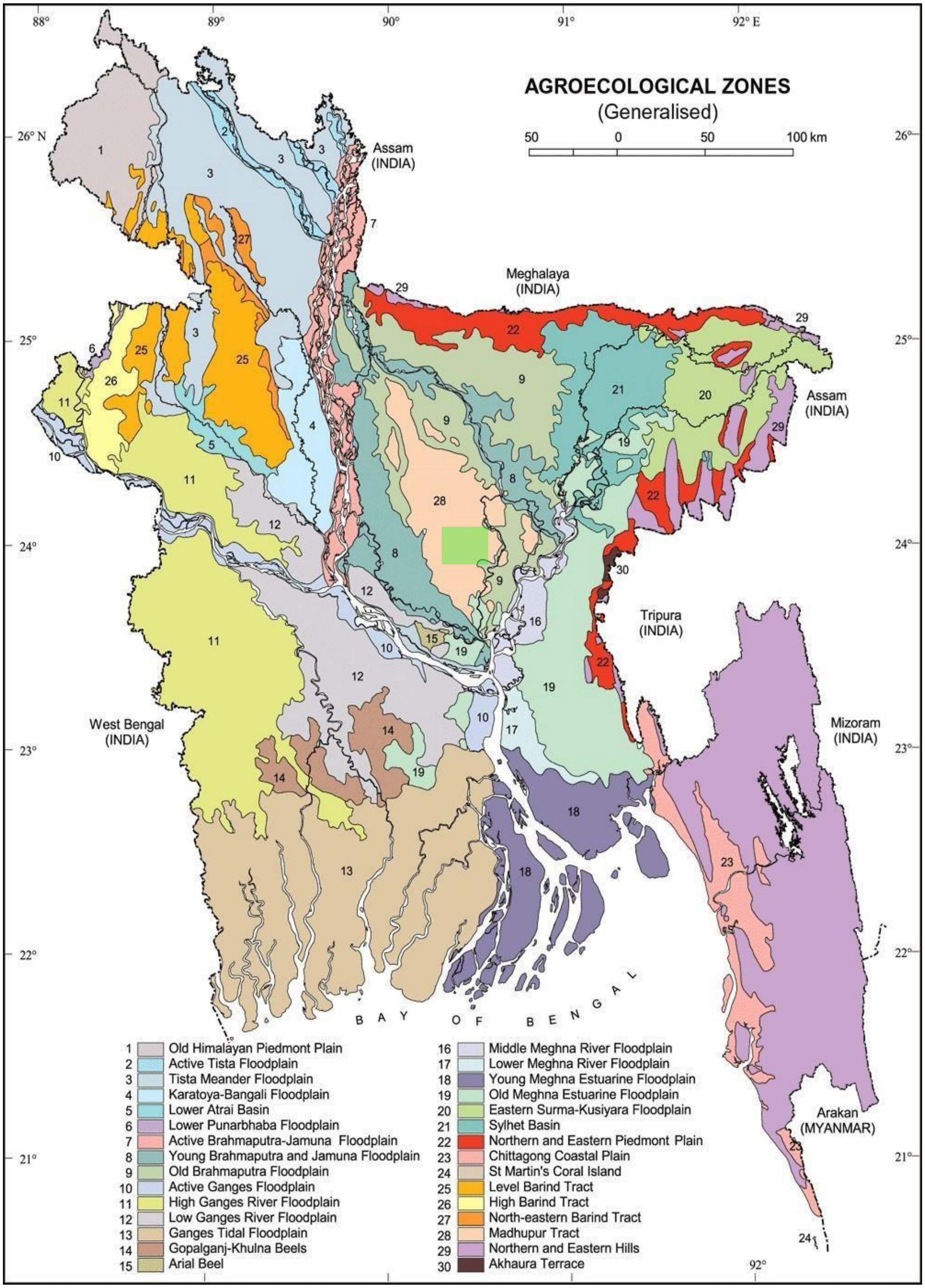
APPENDICES

Appendix I. Map showing the experimental site under study



N B. The green colored mark indicates the experimental site under study.

Appendix II. Characteristics of soil of experimental site is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Boro-Aman-Boro

B. Physical and chemical properties of the initial soil before seed sowing

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural Class	Silty-clay
pH.	6.7
Total N (%)	0.15
Available P (ppm)	22.60
Exchangeable K (meq/ 100 gm soil	0.18
Available Boron (ppm)	3.96
Available Manganese (ppm)	83.26
Available Zinc (ppm)	28.56

Appendix III. Error means square values for Plant height, number of leaves plant^{-1} of tomato

Source of variation	Degrees of freedom	Plant height			No. of leaves plant^{-1}		
		At transplant	30 DAT	70 DAT	At transplant	30 DAT	70 DAT
Replication	2	0.2178	0.19	0.73	1.86	0.14	5.14
Treatment	6	12.8179	92.94	466.48	98.21	128.11	734.21
Error	12	0.3944	0.55	0.33	0.32	1.09	1.25

*Significant at 5% level of probability ** Significant at 1% level of probability

Appendix IV. Error means square values for Number of branches plant^{-1} and Number of leaves branch^{-1} of tomato

Source of variation	Degrees of freedom	Number of branches plant^{-1}			Number of leaves branch^{-1}		
		At transplant	30 DAT	70 DAT	At transplant	30 DAT	70 DAT
Replication	2	0.33	0.143	0.19	0.76	0.14	1.00
Treatment	6	7.19	9.43	16.41	5.30	14.98	41.87
Error	12	0.33	0.48	0.58	0.21	0.37	0.44

*Significant at 5% level of probability ** Significant at 1% level of probability

Appendix V. Error means square values for Number of fruits plant^{-1}, Fruit dry weight and Fruit yield plant^{-1} of tomato

Source of variation	Degrees of freedom	Number of fruits plant^{-1}	Fruit dry weight (g)	Fruit yield plant^{-1}
Replication	2	1.86	543.98	0.004
Treatment	6	45.60	508.29	0.47
Error	12	0.58	483.85	0.018

*Significant at 5% level of probability   ** Significant at 1% level of probability