The impact of organic fertilizers as integrated nutrient management strategies on the benefit cost ratio and yield of tomato (*Solanum lycopersicum* l.).

Ruksana Khan[1], Amit Saurabh[2,*], Yashpal Singh Bisht[2], Anand Singh Rawat[2], Megha Aheer[2], Deepak Kumar[3], Nazam Khan[4], Priya Thakur[1], Vedika Sharma[1], Diksha Saini[1], Himanshi Kapoor[1] and Mamta Pathania[1]

[1] Ph.D. Research Scholar, Department of Horticulture, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, Himachal Pradesh-173101, India;

[2] Assistant Professor, Department of Horticulture, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, Himachal Pradesh-173101, India;

[3] Assistant Professor, Department of Soil Science and Agricultural Chemistry, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, Himachal Pradesh-173101, India;

[4] Assistant Professor, Department of Clinical Labortary Sciences, College of Applied Medical Sciences,
Shaqra University, Kingdom of Saudi Arabia;

[*]Correspondance: dramitsaurabh@gmail.com

Abstract: The field study was conducted at Vegetable Experimental Farm Cchapang, Dr Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib Eternal University at Sirmaur (H.P.) to know the efficacy of organic fertilizers as integrated nutrient management practice on vegetative and yield attributes in Tomato (*Solanum lycopersicum* L.). Variety Heemsona was selected for the investigation. A Randomized Block Design was used in the investigation. There were 25 treatment combinations which were replicated thrice. The maximum yield was calculated under plants treated with vermicompost but highest B:C ratio was recorded under treatment combination VAM as the quantity of VAM applied per plot was very less as compared to organic fertilizers leading to lesser cost price, more benefit and gradually more benefit cost ratio.

Keywords: Benefit, Integrated, Nutrient, Management, Tomato, Yield,

1. Introduction

Tomato (*Solanum lycopersicum* L.) is native to Peru Ecuador region (Jenkins, 1948). This crop is indigenous to Central and South America (Vavilov, 1951). The Indian subcontinent is capable of producing tomato in large quantity. Being diploid, its chromosomal number is 2n=24. It belongs to the Solanaceae family. It is a significant crop which is grown extensively over the world due to its high nutritional value, therefore also goes by the name "poor man's orange.” Tomato is one of the important vegetable crops grown around the world due to its diverse adaptability, high yielding potential, and suitability for a number of usages as fresh and processed food industries. It is the most abundantly planted for multipurpose as garden vegetable (Kumar et al. 2018). It is a tropical day neutral crop that is primarily self-pollinated, though sometimes cross-pollination also occurs. The optimal environmental conditions for growth and flowering observed to be 25 to 30^{0}C day temperature and 16 to 20^{0}C night temperature along with about six hours of sunlight, whereas for fruit set temperature between 18 to 24^{0}C is reported best. Tomato can be grown successfully on a wide range of soil types, from sandy to fine textured, but best suitable soil is with the high organic content and pH range of 5.5-7.0 is required for best cultivation.

Our goal is to promote sustainable agriculture through the use of biological and organic resources for crop production. According to (Kaur et al. 2017), biofertilizers improve nitrogen fixation and nutrient availability for plants. Phosphorus has an important role in plant growth and development. The majority of soils worldwide are phosphorus-deficient (Shahid et al. 2012). Chemical fertilizers cause phosphorus to form complexes with Al or Fe in acidic soils and Ca in calcareous soils, making it inaccessible to plants (Namli et al. 2017). Phosphate-solubilizing microorganisms (PSMs) convert insoluble phosphate to soluble forms by acidification, exchange reactions, and chelation (Olanrewaju et al. 2017). PSBs offer persistent phosphorus supply, stimulate nitrogen fixation, and synthesize growth-promoting chemicals such as antibiotics and side spores (Park et al. 2016 and Amanullah and Khan, 2015).

The bio-intensive management of crops by using biofertilizers shows promising results in terms of increase in crop yield, improvement of soil fertility, enhanced plant development, reduction in production costs along with negligible impact on environment. Various microorganisms, including nitrogen-fixing soil bacteria (*Azotobacter* and *Rhizobium*), nitrogen fixing cyanobacteria (*Anabaena*), phosphate-solubilizing bacteria (*Pseudomonas*) and arbuscular mycorrhizal fungi, which help to retain moisture in soil and facilitate the nutrient flow in plants are commonly used as biofertilizers. Nitrogen fixing bacteria, *Azotobacter* secretes substances like pantathonic acid and gibberellins that aid in root growth. In addition, it secretes ammonia into the rhizosphere, which aids plant nutrient uptake (Narula and Gupta, 1986). Due to the low levels solubility of phosphorus, which hinders its mobility, phosphate solubilizing bacteria (PSB) are useful to access phosphorus to the vegetable crops. Bio-fertilizers also help to keep the pH balanced of soil and significantly increase C, N, P, and K content (Ali et al. 2014).

Biofertilizers constituted of living microorganisms therefore observed eco-friendly, effective for long term and cost effective. The use of biofertilizers in combination with the manures and inorganic fertilizer may result in a higher yield and better quality of crop, which increases profit margins of the farmers. These are used in fertigation as well as with the manures. They survive for long time in the soil which has rich organic matter and boost the plant growth and development, production and productivity. Although the use of different types of fertilizers provide good results in terms of production of the crop but show one or the other constraints in terms of availability of organic manures survival of bio-fertilizers for long term in the soil due to lack of organic matter and use of excessive inorganic fertilizers.

2. Material and methods

2.1. Experimental site.

The research trial was carried out for two years 2023 and 2024 at Chhapang Research farm, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, District Sirmour, Himachal Pradesh. The experimental site was located 912 meters above sea level at 30º44'20"

North and 77º18'53" East. Because the experimental site is located in Himachal Pradesh's semitemperate, semi-humid mid-hill agro climatic zone, it experiences scorching summers and freezing winters.

2.2. Raising of nursery and transplanting

The nursery of Heem Sohna variety was raised under naturally ventillated polyhouse at Chhapang research farm. The seeds were sown on 4th April, 2023 and 1st April, 2024. Tomato seedlings were raised in seed beds each having dimension of 1 m × 1 m. The soil was properly prepared and transformed into a loose, friable state to achieve good tilth. In each seedbed, we had sown 1000 hybrids seeds. To give seedlings a healthy environment for growth, weeding and light watering was done as needed.

In an approx. 500m^2 land, 75 plots were prepared having size 2.1m × 1.8m and 80cm path between two adjacent rows. The seedlings were transplanted on 9th May, 2023 and 11th May, 2024. Healthy and uniform seedlings that were 40 to 45 days old were transplanted into the experimental plots in the afternoon after uprooting from the seed bed during the morning hours. To reduce harm to the roots, the seedbed was irrigated before the seedlings were pulled out from nursery beds. After transplanting the light irrigation was done twice a day during the initial days.

2.3. Collection of organic, inorganic and biofertilizers

The organic manures used in the experiment were FYM, Vermicompost which were collected from Dairy farm and Vermicompost Unit located at Eternal University and Neem cake and Inorganic fertilizer was procured form the local market. Biofertilizers like *Azospirillum*, *Azotobacter*, PSB, *Trichoderma* and VAM were procured from Organic Department, CSKHPKVV Palampur.

2.4. Experimental details

The hybrid used in the experiment was Heem sohna. Plot size was 2m × 2m. Different organic manures, bio fertilizers, inorganic fertilizers along with their combinations were used in the experiment. The rate of applications of different organic manures and bio fertilizers are FYM @ 25tons/ha, Vermicompost @ 5tons/ha, Neemcake @ 2tons/ha, *Azospirillum* @ 400g/ha, *Azotobacter* @ 400g/ha, PSB @ 400g/ha, *Trichoderma* @ 400g/ha and VAM @ 400g/ha. There were 25 different treatment combinations which were replicated thrice.

Table no.1- The details of the treatment combinations

Treatments	Treatment Combination
T_1	Control
T_2	FYM

T_3	Vermicompost
T_4	Neem cake
T_5	*Azospirillum*
T_6	*Azotobacter*
T_7	PSB
T_8	*Trichoderma*
T_9	VAM
T_{10}	FYM + 50% NPK
T_{11}	FYM + 100% NPK
T_{12}	Vermicompost + 50% NPK
T_{13}	Vermicompost + 100% NPK
T_{14}	Neem cake + 50% NPK
T_{15}	Neem cake + 100% NPK
T_{16}	*Azospirillum* + 50% NPK
T_{17}	*Azospirillum* + 100% NPK
T_{18}	*Azotobacter* + 50% NPK
T_{19}	*Azotobacter* + 100% NPK
T_{20}	PSB + 50% NPK
T_{21}	PSB + 100% NPK
T_{22}	*Trichoderma* + 50% NPK
T_{23}	*Trichoderma* + 100% NPK
T_{24}	VAM + 50% NPK
T_{25}	VAM + 100% NPK

3. Statistical Analysis

Analysis of Variance and means comparison from each treatment combination by using General linear model. Mean values were compared using DMRT at a significance level 0.05. Correlation and regression line was also worked out between different observations using SPSS version 20.00.

4. Result and discussion

The systemic approach to examine the economic viability of the research work, the benefit cost ratio have been worked out.

4.1 Cost price

4.1.1 Total fixed cost

Fixed cost is defined as the expenses that do not change with the level of any production and treatments. Here, it consists of cost of land and maintenance cost which got changed with time. For both the consecutive years and pooled analysis, the total fixed cost have been depicted in table no. 4.58 **Table no2 Total Fixed Cost**

	2023	**2024**	**Pooled**

Treatment	Land cost	Maintenance cost	Fixed cost	Land cost	Maintenance cost	Fixed cost	Land cost	Maintenance cost	Fixed cost
T_1	5	2.50	7.50	7	3.50	10.50	6	3	9
T_2	5	2.50	7.50	7	3.50	10.50	6	3	9
T_3	5	2.50	7.50	7	3.50	10.50	6	3	9
T_4	5	2.50	7.50	7	3.50	10.50	6	3	9
T_5	5	2.50	7.50	7	3.50	10.50	6	3	9
T_6	5	2.50	7.50	7	3.50	10.50	6	3	9
T_7	5	2.50	7.50	7	3.50	10.50	6	3	9
T_8	5	2.50	7.50	7	3.50	10.50	6	3	9
T_9	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{10}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{11}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{12}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{13}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{14}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{15}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{16}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{17}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{18}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{19}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{20}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{21}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{22}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{23}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{24}	5	2.50	7.50	7	3.50	10.50	6	3	9
T_{25}	5	2.50	7.50	7	3.50	10.50	6	3	9

4.1.2 Total Variable Cost

Variable cost varies with the season. It includes all the items required during the cropping season. Details are mentioned in table no. 3, 4 and 5.

Table no.3 Total Variable Cost for year 2023

Treatment	Seed	Fertilizer	Labour	Plant Protection	Staking	Irrigation	Total
T_1	1.44	0.00	0.15	25	2.50	3	32.09
T_2	1.44	80.00	0.15	25	2.50	3	112.09
T_3	1.44	93.20	0.15	25	2.50	3	125.29
T_4	1.44	120.00	0.15	25	2.50	3	152.09
T_5	1.44	96.00	0.15	25	2.50	3	128.09
T_6	1.44	0.80	0.15	25	2.50	3	32.89
T_7	1.44	0.60	0.15	25	2.50	3	32.69
T_8	1.44	1.60	0.15	25	2.50	3	33.69
T_9	1.44	1.60	0.15	25	2.50	3	33.69
T_{10}	1.44	1.36	0.15	25	2.50	3	33.45
T_{11}	1.44	82.11	0.15	25	2.50	3	114.20
T_{12}	1.44	63.17	0.15	25	2.50	3	95.26
T_{13}	1.44	63.17	0.15	25	2.50	3	95.26
T_{14}	1.44	98.53	0.15	25	2.50	3	130.62
T_{15}	1.44	101.07	0.15	25	2.50	3	133.16
T_{16}	1.44	0.82	0.15	25	2.50	3	32.91
T_{17}	1.44	0.84	0.15	25	2.50	3	32.93
T_{18}	1.44	0.62	0.15	25	2.50	3	32.71
T_{19}	1.44	0.63	0.15	25	2.50	3	32.72
T_{20}	1.44	1.64	0.15	25	2.50	3	33.73
T_{21}	1.44	1.68	0.15	25	2.50	3	33.77
T_{22}	1.44	1.64	0.15	25	2.50	3	33.73
T_{23}	1.44	1.68	0.15	25	2.50	3	33.77
T_{24}	1.44	1.40	0.15	25	2.50	3	33.49
T_{25}	1.44	1.43	0.15	25	2.50	3	33.52

Table no.4 Total Variable Cost for year 2024

Treatment	Seed	Fertilizer	Labour	Plant Protection	Staking	Irrigation	Total

T_1	2.04	0.00	0.30	30	3	3.25	38.59
T_2	2.04	85.00	0.30	30	3	3.25	123.59
T_3	2.04	97.00	0.30	30	3	3.25	135.59
T_4	2.04	122.00	0.30	30	3	3.25	160.59
T_5	2.04	100.00	0.30	30	3	3.25	138.59
T_6	2.04	1.60	0.30	30	3	3.25	40.19
T_7	2.04	1.00	0.30	30	3	3.25	39.59
T_8	2.04	2.50	0.30	30	3	3.25	41.09
T_9	2.04	2.24	0.30	30	3	3.25	40.83
T_{10}	2.04	2.00	0.30	30	3	3.25	40.59
T_{11}	2.04	90.00	0.30	30	3	3.25	128.59
T_{12}	2.04	65.00	0.30	30	3	3.25	103.59
T_{13}	2.04	67.00	0.30	30	3	3.25	105.59
T_{14}	2.04	100.00	0.30	30	3	3.25	138.59
T_{15}	2.04	103.70	0.30	30	3	3.25	142.29
T_{16}	2.04	1.15	0.30	30	3	3.25	39.74
T_{17}	2.04	1.50	0.30	30	3	3.25	40.09
T_{18}	2.04	1.00	0.30	30	3	3.25	39.59
T_{19}	2.04	1.20	0.30	30	3	3.25	39.79
T_{20}	2.04	2.04	0.30	30	3	3.25	40.63
T_{21}	2.04	2.50	0.30	30	3	3.25	41.09
T_{22}	2.04	2.00	0.30	30	3	3.25	40.59
T_{23}	2.04	2.25	0.30	30	3	3.25	40.84
T_{24}	2.04	2.05	0.30	30	3	3.25	40.64
T_{25}	2.04	2.43	0.30	30	3	3.25	41.02

Table no.5 Total Variable Cost for pooled analysis

Treatment	Seed	Fertilizer	Labour	Plant Protection	Staking	Irrigation	Total

T_1	1.74	0.00	0.22	27.50	2.75	3.12	35.33
T_2	1.74	85.00	0.22	27.50	2.75	3.12	120.33
T_3	1.74	97.00	0.22	27.50	2.75	3.12	132.33
T_4	1.74	122.00	0.22	27.50	2.75	3.12	157.33
T_5	1.74	100.00	0.22	27.50	2.75	3.12	135.33
T_6	1.74	1.60	0.22	27.50	2.75	3.12	36.93
T_7	1.74	1.00	0.22	27.50	2.75	3.12	36.33
T_8	1.74	2.50	0.22	27.50	2.75	3.12	37.83
T_9	1.74	2.24	0.22	27.50	2.75	3.12	37.57
T_{10}	1.74	2.00	0.22	27.50	2.75	3.12	37.33
T_{11}	1.74	90.00	0.22	27.50	2.75	3.12	125.33
T_{12}	1.74	65.00	0.22	27.50	2.75	3.12	100.33
T_{13}	1.74	67.00	0.22	27.50	2.75	3.12	102.33
T_{14}	1.74	100.00	0.22	27.50	2.75	3.12	135.33
T_{15}	1.74	103.70	0.22	27.50	2.75	3.12	139.03
T_{16}	1.74	1.15	0.22	27.50	2.75	3.12	36.48
T_{17}	1.74	1.50	0.22	27.50	2.75	3.12	36.83
T_{18}	1.74	1.00	0.22	27.50	2.75	3.12	36.33
T_{19}	1.74	1.20	0.22	27.50	2.75	3.12	36.53
T_{20}	1.74	2.04	0.22	27.50	2.75	3.12	37.37
T_{21}	1.74	2.50	0.22	27.50	2.75	3.12	37.83
T_{22}	1.74	2.00	0.22	27.50	2.75	3.12	37.33
T_{23}	1.74	2.25	0.22	27.50	2.75	3.12	37.58
T_{24}	1.74	2.05	0.22	27.50	2.75	3.12	37.38
T_{25}	1.74	2.43	0.22	27.50	2.75	3.12	37.76

4.2 Total cost price

Cost price shall be calculated by adding the total fixed cost and total variable cost. The details for the total cost price of both the years and pooled data is given below.

Table no.6 Total Cost Price

Treatment	Treatment Combinations	2023	2024	Pooled
T_1	Absolute Control	39.59	49.09	44.33
T_2	FYM+ 100% NPK (Standard check)	119.59	134.09	129.33
T_3	FYM	132.79	146.09	141.33
T_4	Vermicompost	159.59	171.09	166.33
T_5	Neem cake	135.59	149.09	144.33
T_6	Azospirillum	40.39	50.69	45.93
T_7	Azotobacter	40.19	50.09	45.33
T_8	PSB	41.19	51.59	46.83
T_9	Trichoderma	41.19	51.33	46.57
T_{10}	VAM	40.95	51.09	46.33
T_{11}	FYM + 50% NPK	121.70	139.09	134.33
T_{12}	Vermicompost + 50% NPK	102.76	114.09	109.33
T_{13}	Vermicompost + 100% NPK	102.76	116.09	111.33
T_{14}	Neem cake + 50% NPK	138.12	149.09	144.33
T_{15}	Neem cake + 100% NPK	140.66	152.79	148.03
T_{16}	Azospirillum + 50% NPK	40.41	50.24	45.48
T_{17}	Azospirillum + 100% NPK	40.43	50.59	45.83
T_{18}	Azotobacter + 50% NPK	40.21	50.09	45.33
T_{19}	Azotobacter + 100% NPK	40.22	50.29	45.53
T_{20}	PSB + 50% NPK	41.23	51.13	46.37
T_{21}	PSB + 100% NPK	41.27	51.59	46.83
T_{22}	Trichoderma + 50% NPK	41.23	51.09	46.33
T_{23}	Trichoderma + 100% NPK	41.27	51.34	46.58
T_{24}	VAM + 50% NPK	40.99	51.14	46.38
T_{25}	VAM + 100% NPK	41.02	51.52	46.76

4.3 Selling price

This includes the total value formed by selling the produce in the market. It is calculated by multiplying yield/m^2 with price/unit (kg).

Table no.7 Total Selling Price

Treatment	2023			2024			Pooled		
	Yield/m^2	Price/kg	Selling price	Yield/m^2	Price/kg	Selling price	Yield/m^2	Price/kg	Selling price
T_1	5.75	100.00	574.90	6.70	90.00	603.27	6.23	95.00	591.47
T_2	11.86	100.00	1186.44	12.31	90.00	1108.21	12.09	95.00	1148.45
T_3	10.00	100.00	999.69	10.61	90.00	955.06	10.30	95.00	978.91
T_4	13.27	100.00	1327.20	14.51	90.00	1306.33	13.89	95.00	1319.87
T_5	6.78	100.00	677.85	7.74	90.00	696.30	7.26	95.00	689.47
T_6	8.02	100.00	801.66	8.88	90.00	798.98	8.45	95.00	802.48
T_7	6.99	100.00	698.88	7.84	90.00	705.70	7.41	95.00	704.42
T_8	7.56	100.00	756.22	8.80	90.00	791.89	8.18	95.00	777.14
T_9	10.13	100.00	1012.84	10.53	90.00	947.82	10.33	95.00	981.34
T_{10}	10.86	100.00	1086.23	11.39	90.00	1025.08	11.13	95.00	1056.97
T_{11}	11.07	100.00	1107.44	12.07	90.00	1086.33	11.57	95.00	1099.37
T_{12}	12.54	100.00	1253.69	13.71	90.00	1234.06	13.12	95.00	1246.81
T_{13}	12.94	100.00	1293.76	14.08	90.00	1266.77	13.51	95.00	1283.11
T_{14}	7.79	100.00	779.20	8.71	90.00	783.52	8.25	95.00	783.64
T_{15}	8.62	100.00	861.66	9.67	90.00	870.20	9.14	95.00	868.56
T_{16}	8.19	100.00	818.69	9.38	90.00	844.02	8.78	95.00	834.33
T_{17}	9.80	100.00	980.41	10.54	90.00	948.27	10.17	95.00	966.17
T_{18}	9.50	100.00	949.97	10.30	90.00	926.56	9.90	95.00	940.26
T_{19}	7.75	100.00	775.21	8.84	90.00	795.53	8.30	95.00	788.09
T_{20}	7.68	100.00	768.05	8.90	90.00	801.21	8.29	95.00	787.69
T_{21}	9.06	100.00	905.53	10.14	90.00	912.86	9.60	95.00	911.91
T_{22}	7.17	100.00	717.39	8.21	90.00	739.24	7.69	95.00	730.91
T_{23}	7.25	100.00	725.02	8.27	90.00	744.65	7.76	95.00	737.40
T_{24}	8.10	100.00	809.92	8.92	90.00	802.68	8.51	95.00	808.35
T_{25}	8.08	100.00	808.44	8.88	90.00	799.41	8.48	95.00	805.92

4.4 Benefit cost ratio

Benefit cost ratio was calculated after working out the benefit which is the difference between selling price and cost price. BC ratio is a ratio between benefit and cost price. Results revealed that maximum yield/m^2 (13.27, 14.51 and 13.89kg/m^2) was recorded under vermicompost. It was sold at the rate of 100, 90 and 95 and having maximum selling price but when BC ratio was worked out then VAM recorded maximum BC ratio (25.53, 17.47 and 20.07) respectively for both the years and pooled analysis. Although vermicompost recorded maximum yield but B:C ratio was maximum in treatment with VAM because the quantity of VAM applied per plot was very less as compared to organic fertilizers leading to lesser cost price, more benefit and gradually more benefit cost ratio. The results were similar to Singh et al. 2021.

Table no.8 Benefit Cost Ratio

Treatment	2023		2024		Pooled	
	Benefit	BC ratio	Benefit	BC ratio	Benefit	BC ratio
T_1	535.31	13.52	554.18	11.29	547.14	12.34
T_2	1066.85	8.92	974.12	7.26	1019.12	7.88
T_3	866.90	6.53	808.97	5.54	837.58	5.93
T_4	1167.61	7.32	1135.24	6.64	1153.54	6.94
T_5	542.26	4.00	547.21	3.67	545.14	3.78
T_6	761.27	18.85	748.29	14.76	756.55	16.47
T_7	658.69	16.39	655.61	13.09	659.09	14.54
T_8	715.03	17.36	740.30	14.35	730.31	15.60
T_9	971.65	23.59	896.49	17.47	934.77	20.07
T_{10}	1045.28	25.53	973.99	19.06	1010.64	21.81
T_{11}	985.74	8.10	947.24	6.81	965.04	7.18
T_{12}	1150.93	11.20	1119.97	9.82	1137.48	10.40
T_{13}	1191.00	11.59	1150.68	9.91	1171.78	10.53
T_{14}	641.08	4.64	634.43	4.26	639.31	4.43
T_{15}	721.00	5.13	717.41	4.70	720.53	4.87
T_{16}	778.28	19.26	793.78	15.80	788.85	17.35
T_{17}	939.97	23.25	897.68	17.74	920.34	20.08
T_{18}	909.77	22.63	876.47	17.50	894.93	19.74
T_{19}	734.99	18.27	745.24	14.82	742.56	16.31
T_{20}	726.82	17.63	750.08	14.67	741.32	15.99
T_{21}	864.25	20.94	861.27	16.69	865.08	18.47
T_{22}	676.15	16.40	688.15	13.47	684.58	14.78
T_{23}	683.75	16.57	693.31	13.50	690.82	14.83
T_{24}	768.93	18.76	751.54	14.70	761.97	16.43
T_{25}	767.42	18.71	747.89	14.52	759.16	16.24

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