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Assessment of Effects of Package of Practices on Plant Growth Parameters, Fruit Yield and Monetary Returns from Tomato (*Lycopersicon esculentum* L.) Crop Grown in Farmers Field at Semi-Arid Alfisols of Karnataka

[1]M.GOVINDAPPA, [1] Ph.D. Scholar, *govind.gowda2006@gmail.com*

ABSTRACT - Keeping technological complexity of adoption and prove the importance of 'package of practices' of tomato, a field experiment has been conducted in a farmer's field in Agrahara village, Chintamani in Karnataka. The package of practices is a set of crop-based technologies intended to provide maximum yield and monetary returns and maintain soil fertility in the field. They would promote use of regional/zonal adopted improved varieties with low degree of susceptibility to pests and diseases. The field experiment involved 7 treatments viz., (i) T1: Control (625:625:625 kg NPK + 35 t FYM + 450 kg PC + EADI + NAVC + NABF & MN); (ii) T2: Farm Yard Manure (FYM) + Recommended Dose of Fertilizer (RDF) + Mulching; (iii) T3: FYM + RDF + Vermi-Compost (VC) + Mulching; (iv) T4: FYM + RDF + VC + Micro Nutrient (MN) + Mulching; (v) T5: FYM + Mulching; (vi) T6: RDF + Mulching; and (vii) T7: FYM + RDF + VC + MN + Trichoderma (TD) + Mulching. Observations on plant height (cm), number of leaves, stem girth (cm) and number of branches were recorded on 30, 60, 90 and 120 days after transplanting (DATP) in each treatment. Total number of fruits/plant, fruit yield/acre, number of roots/plant, root length (cm) and soil microbial biomass were recorded at harvest of tomato crop. Cowpea and ridge gourd were grown as relay crops at 120 DATP of tomato (*before harvest of tomato*) with seeds sown between plants at spacing of 2 ft x 2 ft (cowpea) & 2.5 ft x 2.5 ft (ridge gourd). In case of plant height, T7 was superior on 30, 90 & 120 DATP, while T1 was superior on 60 DATP. T7 had maximum plant height of 175.5 cm on 120 DATP. In case of No. of leaves, T4 on 30, T2 on 60, T7 on 90 & T4 on 120 DATP were superior. T4 had maximum of 36 leaves on 120 DATP. In case of stem girth, T7 was superior on 30, 60, 90 & 120 DATP with stem girth of 8.7 cm on 120 DATP. In case of No. of branches, T7 was superior on 30, 60, 90 & 120 DATP with maximum of 28 branches on 120 DATP. Effects of treatments on changes in plant height, No. of leaves, stem girth and No. of branches were assessed based on regression model of each variable using observations recorded on different days after planting. The rate of change in plant height was maximum in T7 (1.968 cm/day), while it was minimum in T6 (1.139 cm/day). The coefficient of determination (R^2) for assessing changes in plant height ranged from 0.715 for T5 to 0.909 for T1. The rate of change in number of leaves was maximum in T4 (0.348/day), while it was minimum in T6 (0.225/day). The R^2 for assessing changes in number of leaves ranged from 0.69 for T7 to 0.913 for T4. The rate of change in stem girth was maximum in T7 (0.078 cm/day), while it was minimum in T1 (0.06 cm/day). The R^2 for assessing changes in stem girth ranged from 0.889 for T2 to 0.978 for T7. The rate of change in number of branches was maximum in T7 (0.311/day), while it was minimum in T6 (0.148/day). The R^2 for assessing changes in number of branches ranged from 0.883 for T3 to 0.94 for T1. At harvest, T7 with higher organic dose, minimum synthetics & organic minerals was superior with maximum fruit yield of 112.5 t/ha. T2 was superior with maximum of 16 roots, while T7 was superior with maximum root length of 37.63 cm. Soil microbial biomass was influenced by vegetation, substrate availability & abiotic factors. T7 was superior since it received more organics along with vermicompost & RDF. Based on the study, cost of cultivation incurred on tomato was Rs.82390/-, while fruit yield was

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45000 kg/acre, gross returns of Rs.306000/acre with BC ratio of 3.71 were attained. In cowpea, cost of cultivation incurred was Rs.3710/acre, while green pod yield of 1711 kg/acre, gross returns of Rs.8555/acre with BC ratio of 2.31 were attained. In ridge gourd, cost of cultivation incurred was Rs.8170/acre; while green fingerlings yield of 7436 kg/acre, gross returns of Rs.37180/acre with BC ratio of 4.55 were attained. Based on the study, farmers could attain maximum tomato yield and monetary returns by adopting soil testing, use of optimum FYM, 50% N, 100% P and K, recommended age of seedlings and spacing, optimum plant population, 100 kg neem cake, installing yellow traps, 2 sprays of 4% Neem Seed Kernel Extract & optimum No. of irrigations based on soil moisture/crop water requirement under semi-arid Alfisols.

Key words: Tomato crop, Vegetative growth parameters, Reproductive growth parameters, Package of practices, Fruit yield, Monetary returns, Variability, Correlation, Regression, Alfisols

I. INTRODUCTION

Under horticulture, among different vegetable crops, tomato (*Lycopersicon esculentum* L.) is the leading crop grown in many countries. The crop and its wild varieties have spread throughout the world and has become a world-famous *vegetable* during the last 200 years. Carolus Linnaeus, Father of botanical nomenclature has placed tomato crop in the genus *Solanum* in 1753, and named it as *Solanum lycoperscicum*. Tomato crop is cultivated in all seasons in almost all states in India. Andhra Pradesh, Karnataka, Madhya Pradesh, Odisha, Gujarat, Bihar and West Bengal are the leading tomato producing states in the country. There are 8 vegetable growing zones in India. ICAR has a project on vegetables viz., All-India Co-ordinated Research Project (AICRP) on Vegetables at Varanasi in Uttar Pradesh which has tested many tomato varieties for assessing the performance in different states under varying soil and agro-climatic conditions. Some of the efficient varieties grown are Pusa-120, Pusa Rubby, HS-101, HS-102, Hissar Lalith and Hissar Arun. Expansion in area and increase in production and yield of tomato crop have become possible due to prevalence of optimal growing conditions, apart from increasing demand for tomato. Choice for procurement of high yielding varieties has been increasing under both private and public sectors in all regions. Some factors like availability of fertilizers, credit facility, free electricity for use of borewells, minimum transportation cost and market facility were responsible for an increase in the ever increasing popularity of tomato crop. Farmers could also reduce the cost of cultivation of tomato by re-using the drip mains, laterals, inlets, plastic threads and wooden poles in each season. Continuous tomato production has created a mindset among farmers to grow the crop as a hobby in all seasons. Farmers believe that "*tomato is the only crop that could be cultivated easily & procure some money in a short period*". In Karnataka, tomato cultivation is high in Kolar, Chikkaballapura, Bellary, Haveri and Chitradurga districts due to presence of ideal temperature and *second-largest* market in Asia at Kolar. Although *soil deterioration* and stress on *groundwater* occurred over years, still the farmers have been taking up tomato cultivation with the hope of attaining high yield and monetary returns in a quick period.

Currently, 7.98 million ha of land is under vegetable cultivation with production of 133.74 million tons in India. Among vegetables, potato occupies prime position by contributing about 26.6% to total production. Among *Solanaceous* group of vegetables, tomato occupies 1st position, and contributes 8.6% of total production. Full-fledged demand throughout the year stimulated farmers to grow and market the tomato yield and earn higher returns. Intensified cultivation has created a severe stress on the groundwater level and land in different regions. In India, the area of tomato has increased from 478.8 thousand hectares during 2002-03 to 797 thousand hectares during 2016-17 (increase of 60.07%), while production has increased from 7616.16 to 20708 thousand metric tons during the same period with increase of 3.46% and 6.9% Compounded Annual Growth Rate respectively. The production of tomato has increased due to higher demand, increase in consumption and higher rate of returns. In India, the highest tomato-yielding states are Himachal Pradesh, Uttar Pradesh, Andhra Pradesh and Karnataka with 43.98, 39.49, 37.86 and 33.55 tons/ha respectively, while largest tomato-producing states are Andhra Pradesh, Madhya Pradesh and Karnataka. Karnataka has a cultivable area of 123.85 lakh ha (65% of geographical area) with 70.79 lakh operational holdings and 1.74 ha of mean size of holdings. Small and marginal farmers account for 75% of holdings, but cultivate only 36% of cultivable area. There is an increase of 9 lakh holdings during last 5 years. Karnataka receives normal annual rainfall of 1139 mm through South-West and North-East monsoon and has only 30% of irrigated area. The productivity of fruit crops is 16.73 t/ha, while vegetable crops is 17.23 t/ha, spice crops is 2.51 t/ha, commercial flowers is 7.85 t/ha, medicinal plants is 3 t/ha and aromatic plants is 10 t/ha in the state.

In Karnataka, tomato cultivation has increased because of existence of favorable climatic conditions, apart from shifting of produce to other states and countries [8]. Major crops grown during 1980 were Ragi, Paddy, Jowar, and Pulses. To minimize risk from weather aberrations, the

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crops got replaced by mango and eucalyptus in 2000. There were many open wells during 1970s and plenty of water was available. Tube wells/borewells were initiated during 1990s and water depth was 350-400 feet. During 2010, groundwater depth went beyond 1400 feet in Kolar [7]. Karnataka is divided into 10 Agro-Climatic Zones (ACZs) based on the quantity of rainfall, distribution, soils, texture, depth, physical-chemical properties, elevation, topography, crops and vegetation. The ACZs are (i) North-Eastern Transition Zone; (ii) North-Eastern Dry Zone; (iii) Northern Dry Zone; (iv) Central Dry Zone; (v) Eastern Dry Zone; (vi) Southern Dry Zone; (vii) Southern Zone; (viii) Transition Zone; (ix) Northern Transition Zone; and (x) Hilly and Coastal Zone.

Eastern Dry Zone has semi-arid climate with geographical area of 23832 sq km covering 6 districts of Bangalore Urban, Bangalore Rural, Chikkaballapura, Kolar, Ramanagara and Tumkur. Annual rainfall is about 745-750 mm received from 55-60 rainy days. Minimum and maximum temperatures range from 21-46°C with maximum sunshine hours and degree days. Among soils, 70% are red sandy, while 15% are black, and 15% are lateritic soils. Maximum rainfall is received in kharif, which is the source of water for agriculture and domestic needs. Agriculture depends on community water tanks and open wells during monsoon period, while on borewells during the remaining period. The Central Ground Water Board declared Eastern Dry Zone as "*Danger and over exploited zone for groundwater*" in 2012. Congenial climate helped farmers to adopt horticultural crops to a great extent. Further, the rate of crop diversification in Eastern Dry Zone was moderate from cereals to horticultural crops [16]. Kolar and Chikkaballapura are major vegetable producing districts. Tomato, capsicum, chilly, potato, onion, carrot and beetroot are cultivated in this zone. Factors behind wide-spread tomato cultivation are existence of red soil with high water-holding and drainage capacities, availability of FYM, wooden poles (*Existence of more Eucalyptus forest trees*), cheap twine thread, establishment of nurseries, free electricity, markets, local transportation and bumper harvest. Tomato cultivation was further accelerated with introduction of HYVs and fertilizers supplied by private companies. Promotion and subsidy schemes to farmers intensified tube well drilling and tomato cultivation. Provision of 100% subsidy for "*drip irrigation*" made tomato as highly preferred crop under irrigation. Small and marginal farmers are supplied with agricultural inputs along with finance for agriculture.

Compared to cereals and plantation crops, intensification of production practices is highest in vegetables. Existence of agro-diversity and suitable soils in different regions have enabled the cultivation of vegetable crops over years. Share of horticulture crops in area and production has been increasing due to ideal climatic conditions, apart from improved soil fertility, water availability and low cost of cultivation. During 2012-13, the share of vegetable production in horticulture was highest (60.3%) compared to other horticultural crops. It is a fact that a tremendous increase in food production has occurred at the cost of a significant degradation of soils and water resources, apart from deterioration of ecosystem goods and services. These include biomass, carbon storage, soil health, water storage and supply, biodiversity, social and cultural services. Agriculture sector utilized more than 70% of water drawn from aquifers, streams and lakes. In order to achieve a significant increase in production of any crop, it would require adoption of land management practices and efficient water use through enhanced supply, consistency and timing in irrigation [13] indicated that water would be the critical/limiting factor, but increasing trend in population has made land and water as binding constraints for production. It was also reported that excessive irrigation would delay maturity, harvesting, encourage vine growth, apart from reducing soluble solid content in tomato. Excessive irrigation would lead to deep percolation and seepage loss, and also develop salinity [40].

Technologies developed for crop production must support natural ecosystem and should not create imbalance in ecology. Intensive vegetable cultivation for meeting demand of people would create a threat to natural resources. Profitable crop yield could be attained by adopting recommended practices. Some myths of vegetable growers are (i) "*higher plant population will give more yields"; (ii) "more frequencies of irrigations will give more yields"; (iii) "more number of sprays will provide great control of pest and diseases".* To disprove these myths, economically-viable and ecologically-acceptable practices similar to recommended package of practices of University of Agricultural Sciences should be tested in farmers' field through a field experiment. By adopting soil test based fertilizer application, optimum spacing and plant population, applying irrigations at either critical stages or crop water requirement would avoid excess irrigations and minimize stress on groundwater. Need-based application of plant protection chemicals and adoption of trap crops would significantly reduce pests, crop loss and control measures.

In order to demonstrate and convince farmers about package of practices of tomato crop developed under on-station condition, a field experiment has been conducted under on-farm condition in a farmer's field in Agrahara village with 7 treatments comprising of packages of practices of tomato along with a control representing the farmers practice in 2015-16. The treatments were assessed for their effect on different vegetative and reproductive growth parameters viz., plant height, number of leaves, stem girth, number of branches observed on 30, 60, 90 and 120 days after planting; fruit yield, number of fruits, root number, root length, and soil microbial biomass observed at harvest of crop. An assessment of relationship of plant growth and yield parameters has been made in this paper.

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Rates of change in plant growth parameters from transplanting to 120 days after planting have been assessed based on regression analysis. Based on the field experiment, superior treatments have been identified for large scale adoption by farmers for attaining efficient plant growth and maximum tomato yield with optimal use of natural resources. Before harvest of tomato crop, cowpea and ridge gourd were grown as relay crops for maximizing the monetary returns from the cropping system under semi-arid Alfisols.

II. MATERIALS AND METHODS

A field experiment pertains to implementation of package of practices (PoP) was conducted in Agrahara village in Chintamani taluk of Chikkaballapur district in Karnataka. It was conducted to assess the superiority of the package of practices of tomato for attaining maximum profitable yield with optimum input use under the research study entitled “Socio-Economic and Ecological Dimensions of Tomato *(Lycopersicon esculentum L.) Cultivation in Eastern Dry Zone of Karnataka*” during Kharif season of 2015-16. The details of field experiment and data analysis are described below.

Chikkaballapura district is a newly formed district from the existing Kolar district in Karnataka during 2007-08. It consists of 6 taluks viz., Gudibandae, Chikkaballapura, Siddlaghatta, Gowribidanooru, Chintamani, and Bagepalli (in the order of smallest to largest area). Chikkaballapura is the eastern gateway to Karnataka. It is a land-locked district with rock terrain covering an area of 4208 sq km. The district geographically lies between North Latitude 13’ 13’ 4” to 13’ 58’ 29” and East Longitude 77’21’ 52” to 78’ 12’ 31”. District is bounded by Bangalore and Tumkur districts in the West, Ananthapuram district of Andhra Pradesh in the North, Chittoor district in the East and Kolar district in the South. Total geographical area of the district is 404501 hectares, out of which the percent of the area under forests is 49704 ha (12.28%) and the area under cultivation is 210450 ha (52.02%). Out of this area, the area under irrigation is 45909 ha (21.81%) and the remaining area of cultivable land of 67786 ha (32.21%) is under rainfed condition (Chikkaballapura District, 2015). Land is the important natural entity for agriculture and development. The area under different categories are given in Table 1.

Table 1. Land use pattern (%) in Chikkaballpura District during 2014-15

Taluka	Built-up area	Agriculture	Plantation	Forest	Wasteland	Water bodies
Bagepalli	8.33	32.21	0.18	0.96	57.6	0.72
Chikkaballapura	2.88	39.76	0.18	0.96	57.6	1.36
Chintamani	5.65	47.74	0.56	0.12	45.60	0.33
Gowribidanooru	5.74	36.28	0.08	0.58	56.99	0.33
Gudebundae	3.07	44.30	3.28	2.82	45.74	0.78
Siddlagahatta	5.05	47.6	5.23	0.70	41.08	0.31

Chintamani Taluk

Chintamani taluk is the second-largest taluk after Bagepalli in Chikkaballapura District. The total geographical area of the taluk is 867 sq km and it is situated at an elevation of 865 metres above the mean sea level (MSL). Geographically, it lies between 78^{O} 12’ N, 13^{o} 16’ E, and 77^{O} 51’ N 13^{O} 42’ E. The area under forests is 3243 ha, while the area not available for cultivation is 18263 ha, fallow land is 4043 ha, net area sown is 45366 ha, and area sown more than once is 6264 ha. The taluk consists of six hoblies viz., Ambajidurga, Chintamani Kasaba, Kaiwara, Muragamalla, Munganahalli, and Chilakalanerpu. Among these hoblies, four villages, two from Chintamani Kasaba, one village from Muragamalla, and one from Kaiwara hobli were randomly selected for research study, while in one village belongs to Murgamalla hobli, a field experiment was conducted with the adoption of Package of Practices.

Important field crops grown in the taluka are paddy, maize and ragi. The area under these crops was 389, 4505 and 18003 ha respectively. The total area under field crops was 22901 ha, while the highest area was under ragi crop. The important pulse crops that are cultivated in the taluka are Tur (875 ha), Horse gram (1213 ha), Bengal gram (18 ha), Avarae (229 ha) and Cowpea (484 ha). The total area under pulses accounts for 4819 ha. The total area under food grains, fruit crops, and vegetables were 27700, 9134, and 2380 ha respectively.

Major vegetables grown are tomato, potato, green chilies, onion, and beans. The area and production of these crops was 458 ha and 13886 MT of tomato, 450 ha and 7245 MT of Potato, 70 ha and 1120 MT of Green chilies, 410 Ha and 8485 MT of Onion, and 270 and 3240 MT of Beans. All these crops were under bore well system of irrigation. Among these vegetables, the highest area has been occupied by tomato, which is the major vegetable grown in the taluka. This was the only vegetable in the taluka and grown throughout (all three seasons) the year. The main reason to cultivate tomato as a major vegetable under borewell irrigation was that its average productivity in the study area was higher (30.32 MT/Ha) than the district average (25.59 MT/Ha) and Taluka average productivity (24.64 MT/Ha). It was also due to the existence of optimal climatic conditions. The cultivation of tomato under ridge and furrow system of irrigation would require 18-24 lakh liters of water per season, per crop, per acre. The drip system would also involve 2000 gallons of water per season, per crop, per acre. Since tomato crop was being cultivated in all the three seasons (Kharif, Rabi and summer), the stress on the ground and borewell water was

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very high and alarming as given in Table 2 (CGWB, 2014 : Chikkaballapura, 2014-15).

Table 2. Groundwater situation of Chintamani taluka (2014-15)

Particulars	Quantum
Net annual groundwater availability	5,917 ha m
Existing gross groundwater draft for irrigation	9,701 ha m
Existing gross groundwater draft for domestic & industrial water supply	255 ha m
Existing gross groundwater draft for all uses	9,956 ha m
Allocation for domestic and industrial uses for the next 25 years	255 ha m
Net groundwater availability for future irrigation	26 ha m
Existing stage of groundwater development	168 ha m
Category of the taluka	*Over exploited*

Hence, cultivation of low water requirement crops and irrigation based on the crop critical stages were of top most priority. Tomato is a high water requirement crop and its cultivation was causing severe ground water breeze in the taluk. The package of practices prescribed for the crop indicated that the crop would require only minimum number of irrigations for attaining sustainable and economic yields. In order to investigate the same package with slight modification, a field experiment has been conducted and the results are assessed in this paper.

III. EXPERIMENTAL DETAILS

Keeping the technological complexity of the adoption and to prove the importance of Package of Practices, a field experiment has been conducted at Agrahara village located under Muragamalla Panchayat of Chintamani Taluk. The Package of Practices is a set of the crop-based set of tested and proven scientific production technology intended to restore the natural entities with substantial and increased crop production is implemented. It would also promote the usage of regional and zonal adopted crop varieties which have low to very low degree of susceptibility to pests and diseases. The Package of Practices would also integrate the nutrient, pest & disease, and crop management with the restoration of biotic fauna and flora in the cropping zone.

Details of treatments tested in the study are described below. The experiment was laid out in an area measuring 1910.4 m^2 (half an acre). The length and width of the experimental site was 48.0 m X 39.8 m and the net plot size was 4.8 m X 4.8 m. The study had 7 treatments with 3 replications conducted in a Randomized Complete Block Design (RCBD). It is the design wherein the allocation of treatments would be done on a random basis completely and these treatments will be replicated three times so that the experimental error is minimized to the least level. The 7 treatments tested are

T1: Control (625:625:625 kg NPK + 35 t FYM + 450 kg PC + EADI + NAVC + NABF & MN)

T2: Farm Yard Manure (FYM) + Recommended Dose of Fertilizer (RDF) + Mulching

T3: FYM + RDF + Vermi-Compost (VC) + Mulching

T4: FYM + RDF + VC + Micro Nutrient (MN) + Mulching

T5: FYM + Mulching

T6: RDF + Mulching

T7: FYM + RDF + VC + MN + Trichoderma (TD) + Mulching

Ecological dimensions

Ecological features would consist of soil, water, and existing ecosystem. These are fundamental in any type of crop production. The extent and level of these entities' utilisation and the intensity of the utilisation in tomato crop production were considered in the study zone. The implication developed due to its intensive utilisation without any resting period and without adopting the cropping seasons in the said cropping zone have been considered in the study. The consistent cultivation has resulted in a significant deterioration in the soil health, soil beneficial microbial flora (count), incorporation of non-degradable plastic material to the soil, and over-exploitation of groundwater. The ever increasing area under tomato cultivation has created a significantly higher demand for the standing wooden poles which, in turn, caused tree cutting and deforestation (Eucalyptus species) in the study region.

Soil characteristics

Before initiating tomato farming, the initial soil samples were collected through zig-zag method. Soil samples were obtained by following a quadrangle method of soil sample collection. The samples were analyzed at Krishi Vignan Kendra, Chikkaballapura District. The soil of experimental site is a red sandy loam in texture and is slightly alkaline. The pH of the soil is neutral (7.68) and has an organic carbon content of 0.11%. The electrical conductivity of the soil is 0.3 ds/m, while the available nitrogen is low (66.96 kg/ha), available phosphorous is medium (34.72 kg/ha) and available potassium is medium (305 kg/ha).

Meteorological conditions prevailing during the crop growth period (2015-16)

The meteorological or climatic conditions regarding the monthly rainfall (mm), number of rainy days (number), minimum temperature (°C), maximum temperature (°C), relative humidity (%), mean daily water evaporation (mm) and mean sunshine hours are described in Table 3. The rainy days, rainfall and relative humidity (%) observed in different months are depicted in Fig 1. The minimum and maximum temperatures observed in different months are depicted in Fig 2. The water EVP and number of sunshine hours observed in different months are depicted in Fig 3.

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Table 3. Meteorological observations during the crop growth period in the study area in 2015-16

Month	Rainfall (mm)	Rainy days	Temperature		Relative humidity (%)	Water EVP (mm)	Sunshine Hours (Hr)
			Min temp (°C)	Max temp (°C)			
January	6.2	1	16.86	27.66	73.00	3.49	4.54
February	-	-	17.29	29.99	63.70	5.30	9.66
March	35.2	4	21.32	32.93	68.77	5.27	8.28
April	170.5	5	21.95	33.39	64.70	4.60	7.94
May	160.9	6	23.12	31.78	65.80	3.45	6.95
June	40.1	5	21.47	34.95	70.60	3.05	5.68
July	60.1	5	20.53	28.44	65.12	2.98	6.48
August	162.3	10	20.61	30.35	72.83	2.01	6.10
September	189.8	8	20.27	30.08	71.20	2.47	5.99
October	113.3	7	19.08	30.29	71.54	2.76	7.69
November	349.1	17	17.10	26.92	79.86	1.51	3.26
December	3.0	-	16.03	27.80	74.58	3.27	6.57
Total/Mean	1290.4	68	19.63	30.38	70.14	5.84	6.59

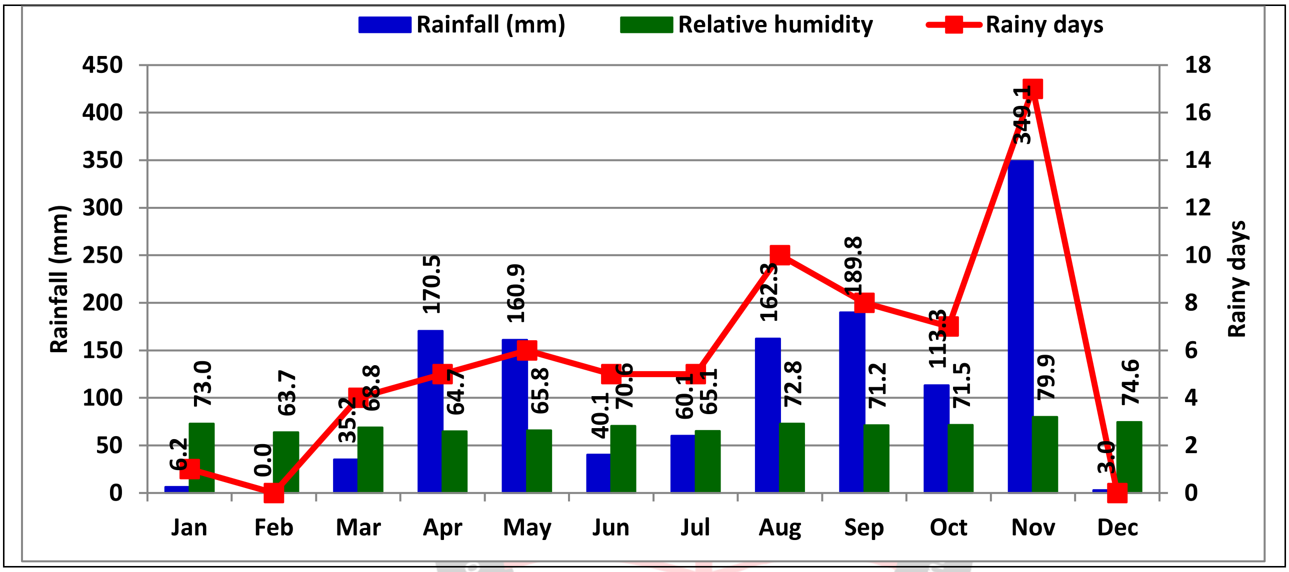

Fig 1. Rainy days, Rainfall and Relative humidity observed in different months during 2015-16

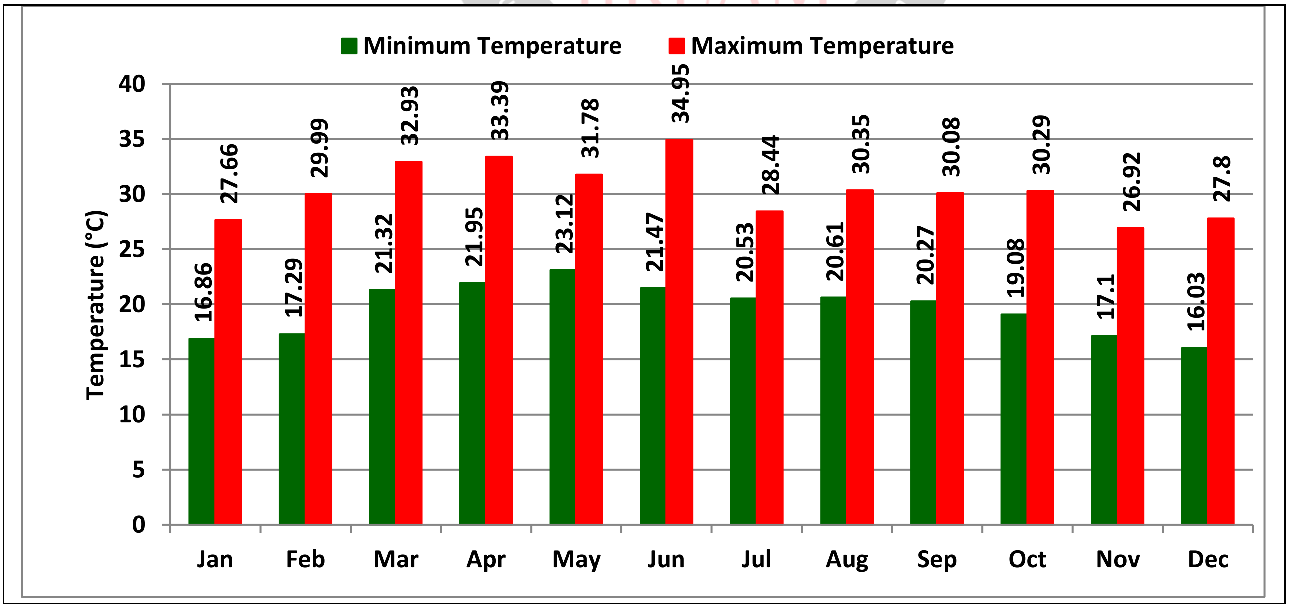

Fig 2. Minimum and Maximum temperature observed in different months during 2015-16

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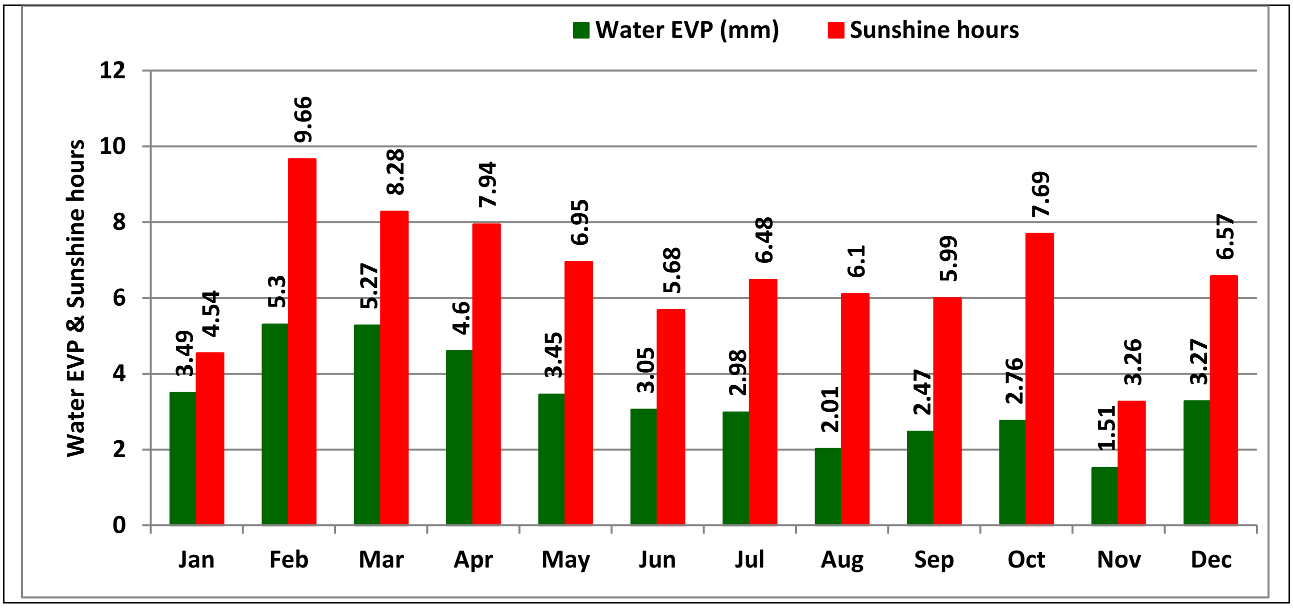

Fig 3. Water EVP and number of Sunshine hours observed in different months during 2015-16

Land preparation: The land was prepared by disc ploughing once and passing the cultivator twice, followed by harrowing to bring the soil into fine seed bed and good tilth. Land was demarcated as per measurements, and inter and intra bunds were laid out. Recommended inputs were imposed into the respective treatments drip emitters. They were laid out and mulching sheet was covered on each planting bed laid out in 3 feet between the rows. At one corner of the bed, punching of black mulching sheet was done every 1.5 feet distance to make the transplanting site (hole) for transplanting the tomato seedlings.

Transplanting: Transplanting of 22-days-old seedlings of Ark Samrat was taken up on 15th May, 2015 and one seedling per hill was transplanted. The recommended aged seedlings of 22-days-old seedlings were transplanted and spacing per plant-to-plant and row-to-row was followed. The number of seedlings per unit area was adopted (5555 seedlings) and drip irrigation was provided. Two weeks after transplanting, the transplanted seedling mortality was assessed. If it was less than 3% (300 seedlings), the re-planting of the same variety was taken up and irrigation was provided.

Observations collected: From randomly-selected 5 plants, the plant height was measured from ground level to the base of the fully opened leaf at 30, 60, 90 and 120 days after transplanting (DATP). After 50% flowering, the height of the plant was taken up to the tip of the main shoot, and mean plant height was worked out and expressed in centimeters. From randomly-selected plants, number of primary branches/plant was recorded at 30, 60, 90 and 120 DATP. At harvest, they were pooled and mean number of branches/plant was determined. The reproductive growth began in 7th week after transplanting. The total number of days taken for the 50% crop flowering was recorded in each treatment. Yield parameters like total number of fruits/plant, fruit size and circumference of the fruits were measured. Number of fruits weighed per kilogram was also determined.

a) Full view of the Field Experiment

b) Fruit yield per plant in T7

Relay crops in the field experiment of tomato

The field experiment was conducted and fruit yields obtained in the plots which received recommended dose of fertilizers and integrated nutrient management practice were recorded. After 120 days of planting, the main crop would be about to mature. Two more crops were taken up in the same block in half acre each. The practice of sowing seeds and growing second crop before harvesting the main crop is called 'relay cropping'. The process of sowing seeds of cowpea and ridge gourd was taken up in between the plants on same mulched row by puncturing the plastic mulch and these are called relay crops.

The first relay crop sown in half acre was cowpea (*Vigna anguculata* L.) in between tomato plants on the same

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mulched row in half acre and ridge gourd (*Luffa acutangula*) in half acre. After 45 days of planting, flowering and pod formation occurred. The vegetative and reproductive growth observations of both crops were recorded. The vigorous vegetative growth and high number reproductive bodies were noticed. The results pertaining to crop yield were recorded. The advantages of relay crops are: (i) Effective usage of crop season and efficient utilisation of soil nutrients; (ii) Land preparation and seedbed preparation would not be required; (iii) Low cost of cultivation of the relay crops; (iv) The crops would fix atmospheric nitrogen through root nodules; (v) The crops would minimize the external nitrogen application and leaching quantity from the topsoil to lower water bodies will be avoided; (vi) Additional income from the relay crops; and (vii) Higher B:C ratio in the entire cropping system.

Statistical analysis

The experimental data of different parameters has been analyzed using different statistical methods. Descriptive statistics viz., minimum, maximum, mean, standard deviation (SD), standard error of mean (SEM), coefficient of variation (CV), skewness and kurtosis have been derived for each variable observed in the study. An assessment has been made about the variability of yield and independent variables and their distribution based on the data collected in the experiment.

Estimates of correlation have been determined between different pairs of variables to assess the magnitude of relationship which could be either positive or negative and would range from -1 to +1. The correlations between variables have been derived for each village and also when pooled over all villages. The correlations have been tested for significance based on t-test as described by [17]. Regression analysis has been carried out in order to predict the tomato yield through different combinations of independent variables. A regression model has been calibrated for predicting the tomato yield through different independent variables. The regression model is as follows:

Y = ± A ± B (Plant height) …………(1)

Y = ± A ± B (Number of flowers) …………(2)

Y = ± A ± B (Stem girth) …………(3)

Y = ± A ± B (Number of branches) …………(4)

In the models, ‘B’ coefficients are the regression coefficients which indicate the rate of change in tomato yield for an unit change in the respective independent variable. Using regression coefficients and their standard errors, significance of regression coefficients could be tested based on t-test as a ratio of regression coefficient of a variable and its standard error (Gomez and Gomez, 1984). A regression model could be assessed for prediction of yield based on estimate of coefficient of determination or predictability (R^2), which would indicate about the percentage of variability in the yield that could be explained by a model (Draper and Smith, 1998).

The differences among 7 treatments used in the field experiment with 3 replications were tested based on F-test under the Analysis of Variance (ANOVA). The differences between each pair of treatments were tested based on the Critical difference (CD) criteria at 5% level of significance as discussed by Gomez and Gomez (1984). If the difference between mean values of two treatments is more than the CD value, the treatments are considered to be statistically different, while if the difference is less than the CD value, the treatments are considered as at par with each other.

IV. RESULTS AND DISCUSSION

Field experiment with Package of Practices

A field experiment was conducted in Agrahara with 7 treatments comprising of package of practices of tomato to assess the variability and superiority of treatments. The changes in vegetative and reproductive growth parameters were assessed. Four vegetative and reproductive growth parameters viz., plant height (cm), number of leaves, stem girth (cm) and number of branches were recorded at different stages on 30, 60, 90 and 120 days after transplanting (DATP) under each treatment and were statistically analyzed. Results based on field experiment conducted in Agrahara with 7 treatments using package of practices of tomato are discussed below.

A set of 7 treatments viz., T1, T2, T3, T4, T5, T6 and T7 were superimposed to different plots in the experiment. Treatment T1 is control which would serve as the check, i.e., all the tomato cultivation practices followed in the region have been followed. The 7 treatments tested are as follows :

T1: Control (625:625:625 kg NPK + 35 tons FYM + 450 kg PC + EADI + NAVC + NABF & MN)
T2: Farm Yard Manure (FYM) + Recommended Dose of Fertilizer (RDF) + Mulching
T3: FYM + RDF + Vermi-Compost (VC) + Mulching
T4: FYM + RDF + VC + Micro Nutrient (MN) + Mulching
T5: FYM + Mulching
T6: RDF + Mulching
T7: FYM + RDF + VC + MN + Trichoderma (TD) + Mulching

Transplanting of seedlings was done on 6th July 2015. About 5555 plants/acre were planted with 3 replications. Plant height (cm), number of leaves, stem girth (cm) and number of branches were recorded on 30, 60, 90 and 120 days after transplanting (DATP) under each treatment and were analyzed. T1 is control which includes all cultivation practices of tomato followed by farmers. Differences among treatments were tested based on Analysis of Variance (ANOVA). Effects of treatments on plant height, number of leaves, stem girth and number of branches were

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tested based on regression model of each variable over time period using observations recorded on different days after planting.

Vegetative growth parameters

Plant height

At 30 DATP, the plant height ranged from 18.5 cm in T3 to 20.6 cm in T7 with mean of 19.6 cm (CV of 3.6%) over different treatments. At 60 DATP, the plant height ranged from 43.9 cm in T5 to 49.2 cm in T1 (Farmer's practice) with mean of 45.8 cm (CV of 4.9%) over different treatments. At 90 DATP, the plant height ranged from 108.0 cm in T6 to 170.0 cm in T7 with mean of 141.2 cm (CV of 15.5%) over different treatments. At 120 DATP, the plant height ranged from 112.3 cm in T6 to 175.5 cm in T7 with mean of 141.4 cm (CV of 18.1%) over different treatments. Based on Analysis of Variance (ANOVA) of treatments, there was no significant difference among treatments for the plant height measured on 30 and 60 DATP, while there was a significant different among treatments on 90 and 120 DATP. The observations of plant height (cm) recorded on different days after planting, along with the descriptive statistics viz., minimum, maximum, mean, standard deviation, coefficient of variation, standard error of mean and critical difference at 5% level of significance are given in Table 4.

Number of leaves

At 30 DATP, the number of leaves ranged from 4.3 in T5 to 6.3 in T4 with mean of 5.2 (CV of 12.5%) over different treatments. At 60 DATP, the number of leaves ranged from 19.6 in T4 to 28.4 in T2 with mean of 23.3 (CV of 14.9%) over different treatments. At 90 DATP, the number of leaves ranged from 24.0 in T6 to 39.1 in T7 with mean of 29.9 (CV of 17.8%) over different treatments. At 120 DATP, the number of leaves ranged from 27.9 in T6 to 36.0 in T4 with mean of 31.2 (CV of 9.0%) over different treatments. Based on ANOVA of treatments, there was no significant difference among treatments for the number of leaves observed on 30, 60 and 120 DATP, while there was a significant difference among treatments on 90 DATP. The observations of number of leaves recorded on different days after planting, along with the descriptive statistics and critical difference at 5% level of significance are given in Table 4.

Stem girth (cm)

At 30 DATP, the stem girth ranged from 1.0 cm in T2 and T3 to 1.9 cm in T7 with mean of 1.3 cm (CV of 26.5%) over different treatments. At 60 DATP, the stem girth ranged from 1.8 cm in T6 to 3.8 cm in T7 with mean of 2.4 cm (CV of 29.6%) over different treatments. At 90 DATP, the stem girth ranged from 4.6 cm in T6 to 7.2 cm in T7 with mean of 5.7 cm (CV of 15.4%) over different treatments. At 120 DATP, the stem girth ranged from 6.2 cm in T1 to 8.7 cm in T7 with mean of 6.9 cm (CV of 12.2%) over different treatments. Based on ANOVA of treatments, there was no significant difference among treatments for the stem girth observed on 30 and 120 DATP, while there was a significant difference among treatments on 60 and 90 DATP. The observations of stem girth (cm) recorded on different days after planting, along with descriptive statistics and critical difference at 5% level of significance are given in Table 4.

Number of branches

At 30 DATP, the number of branches ranged from 2.0 in T5 to 3.4 in T7 with mean of 2.5 (CV of 18.9%) over different treatments. At 60 DATP, the number of branches ranged from 3.9 in T6 to 7.9 in T7 with mean of 5.7 (CV of 23.2%) over different treatments. At 90 DATP, the number of branches ranged from 13.1 in T6 to 27.0 in T7 with mean of 18.8 (CV of 27.7%) over different treatments. At 120 DATP, the number of branches ranged from 14.3 in T6 to 28.1 in T7 with mean of 20.4 (CV of 25.4%) over different treatments. Based on ANOVA of treatments, there was no significant difference among treatments for the number of branches observed on 30 and 120 DATP, while there was a significant difference among treatments on 60 and 90 DATP. The observations of number of branches recorded on different days after planting, along with the descriptive statistics and critical difference at 5% level of significance for comparing the differences between treatments are given in Table 4. There was a significant increase in plant height, number of leaves, stem girth and number of branches in tomato from transplanting to 120 DATP. Analysis of vegetative growth parameters indicated that they significantly contributed for attaining maximum tomato yield and monetary returns.

Table 4. Analysis of variance of growth parameters observed at 30, 60, 90, and 120 days after transplanting (DATP) in tomato crop at Agrahara

Treatments	Plant height (cm)				Number of leaves				Stem girth (cm)				Number of branches			
DATP	30	60	90	120	30	60	90	120	30	60	90	120	30	60	90	120
T1	19.0	49.2	122.7	127.5	4.6	20.2	26.0	29.3	1.1	2.1	4.9	6.2	2.1	6.0	14.3	15.8
T2	20.2	44.4	147.3	149.5	5.6	28.4	29.2	32.8	1.0	2.0	6.3	6.6	2.2	5.1	16.0	18.6
T3	18.5	48.5	132.0	137.3	5.3	20.9	27.5	29.6	1.0	2.2	5.4	6.4	2.6	5.5	20.7	21.9
T4	19.8	46.3	162.4	172.6	6.3	19.6	35.0	36.0	1.2	2.9	6.0	6.7	2.8	6.8	24.1	26.0
T5	19.6	43.9	146.3	115.2	4.3	22.4	28.2	30.0	1.2	2.0	5.6	6.6	2.0	4.8	16.7	17.9
T6	19.7	44.1	108.0	112.3	5.3	24.2	24.0	27.9	1.5	1.8	4.6	7.1	2.5	3.9	13.1	14.3
T7	20.6	44.1	170.0	175.5	5.1	27.2	39.1	32.9	1.9	3.8	7.2	8.7	3.4	7.9	27.0	28.1
Minimum	18.5	43.9	108.0	112.3	4.3	19.6	24.0	27.9	1.0	1.8	4.6	6.2	2.0	3.9	13.1	14.3

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Maximum	20.6	49.2	170.0	175.5	6.3	28.4	39.1	36.0	1.9	3.8	7.2	8.7	3.4	7.9	27.0	28.1
Mean	19.6	45.8	141.2	141.4	5.2	23.3	29.9	31.2	1.3	2.4	5.7	6.9	2.5	5.7	18.8	20.4
SD	0.7	2.3	21.9	25.6	0.7	3.5	5.3	2.8	0.3	0.7	0.9	0.8	0.5	1.3	5.2	5.2
CV (%)	3.6	4.9	15.5	18.1	12.5	14.9	17.8	9.0	26.5	29.6	15.4	12.2	18.9	23.2	27.7	25.4
Sem (+)	0.99	35.1	8	3.28	0.69	1.63	1.9	24	1.01	0.19	0.3	5.37	1.97	0.39	1.27	16
CD (5%)	NS	NS	24	10.11	NS	NS	5.8	NS	NS	0.58	1	NS	NS	1.2	3.9	NS

SD : Standard deviation CV : Coefficient of variation SEM : Standard error of mean
CD : Critical difference DATP : Days after transplanting NS : Not significant

Assessment of changes in growth parameters over a period of time

The changes in effects of treatments on plant height, number of leaves, stem girth and number of branches have been assessed based on regression model of each variable over a period of time using the observations recorded on different days after planting. The results are described in Fig 4 for plant height and number of leaves and Fig 5 for stem girth and number of branches. The rate of change (cm/day) in plant height was found to be maximum in T7 (1.968 cm/day), while it was minimum in T6 (1.139 cm/day). The coefficient of determination (R^2) for assessing the changes in plant height based on regression models of different treatments ranged from 0.715 for T5 to 0.909 for T1. The rate of change (number of leaves/day) in number of leaves was found to be maximum in T4 (0.348/day), while it was minimum in T6 (0.225/day). The coefficient of determination (R^2) for assessing the changes in plant height based on regression models of different treatments ranged from 0.690 for T7 to 0.913 for T4.

The rate of change (cm/day) in stem girth was found to be maximum in T7 (0.078 cm/day), while it was minimum in T1 (0.06 cm/day). The coefficient of determination (R^2) for assessing the changes in stem girth based on regression models of different treatments ranged from 0.889 for T2 to 0.978 for T7. The rate of change (cm/day) in number of branches was found to be maximum in T7 (0.311/day), while it was minimum in T6 (0.148/day). The coefficient of determination (R^2) for assessing the changes in number of branches based on regression models of different treatments ranged from 0.883 for T3 to 0.94 for T1.

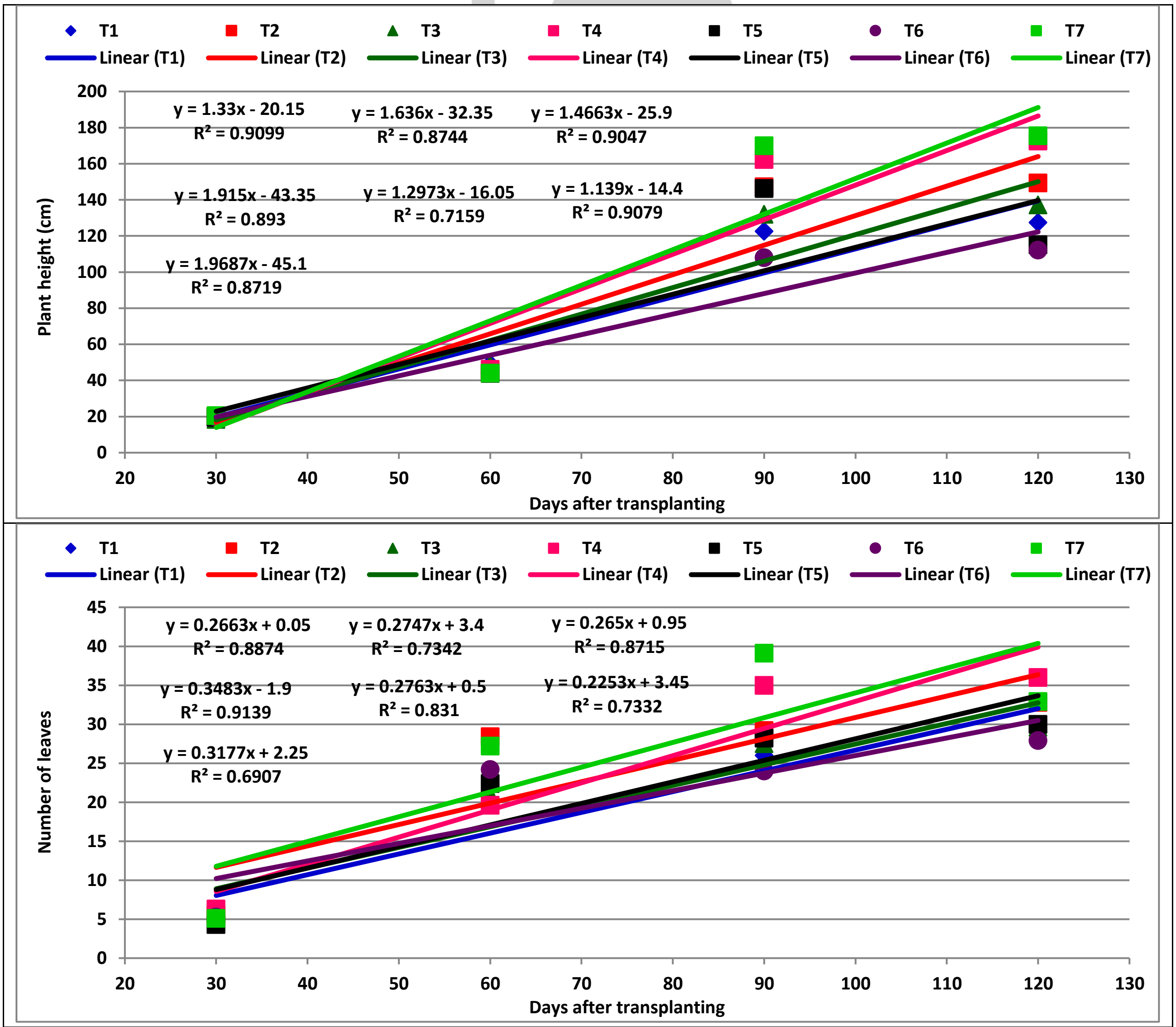

Fig 4. Effect of treatments on plant height and number of leaves in tomato crop in Agrahara

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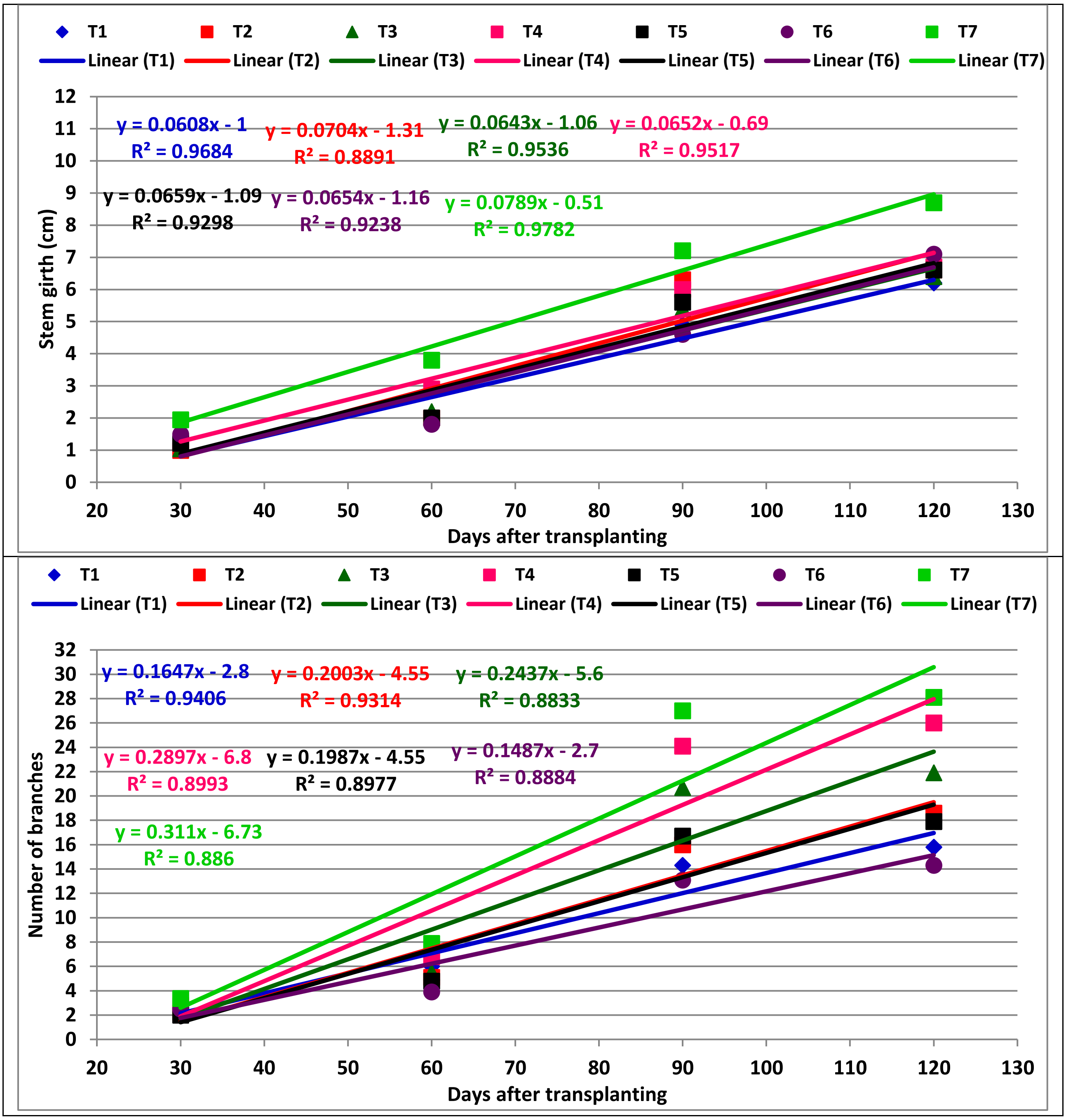

Fig 5. Effect of treatments on stem girth and number of branches in tomato crop in Agrahara

It is observed that there is a significant increase in the vegetative growth of all the four parameters viz., plant height, number of leaves, stem girth, and number of branches in the tomato crop based on the field experiment conducted with different package of practices in Agrahara. The observations on the growth of vegetative growth parameters in the tomato crop indicated that they would greatly contribute for attaining maximum tomato productivity and monetary returns over years. It was similar with the results conducted by Jain et al. (2000); the authors have observed that the drip irrigation has created a lot of interest because of the decreased water requirement and a significant increase in the production of crops.

Reproductive growth parameters

Number of fruits and fruit yield

Growth and development of number of fruits and weight of fruits were analyzed. There was a significant increasing trend in number of fruits weighed per kg in all treatments. Fruit yield ranged from 6 kg/plant in T2 and T6 to 8 kg/plant in T7 with mean of 6.86 kg/plant (CV of 10.1%), while fruit yield (t/ha) ranged from 77.25 t/ha in T6 to 112.50 t/ha in T7 with mean of 92.38 t/ha (CV of 12.7%). Number of fruits/kg ranged from 11 fruits/kg in T7 to 13.7 fruits/kg in T1 and T4 with mean of 12.6 fruits/kg (CV of 8.2%). Based on ANOVA, treatments significantly differed for fruit yield (kg/plant) and fruit yield (t/ha), while there was no significant difference for number of fruits/kg. Based on critical difference, T7 was superior for fruit yield (kg/plant) and fruit yield (t/ha) compared to remaining treatments. T1, T3, T4 and T5 were at par, and were superior to T2 and

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T6. Similarly, T2 and T6 were at par with each other. In case of fruit yield (t/ha), T4 was superior to T1, T2, T3, T5 and T6. T3 was at par with T1; and was superior to T2, T5 and T6. Similarly, T1 was at par with T5; and was superior to T2 and T6. T5 was superior to T2 and T6; while T2 and T6 were at par with each other. Increasing trend was observed in all parameters at vegetative and reproductive stages. This trend was due to sufficient moisture and plant nutrients in available ionic form under mulched condition along with drip irrigation. Growth indices in tomato contributed towards attaining higher yield and monetary returns. With necessary inputs, it is possible to establish good plant height, number of leaves, stem girth and number of branches/plant and attain maximum fruit yield. Based on soil testing, we could minimize use of fertilizers and avoid poisoning of soil, water and other natural entities. The observations on fruit yield harvested (kg/plant), fruit yield per hectare (tons/ha) and mean number of fruits/kg attained under 7 treatments of package of practices of tomato along with the descriptive statistics and critical difference at 5% level of significance for comparing the difference between treatments are given in Table 5. The effects of treatments on fruit yield harvested (kg/plant), fruit yield per hectare (tons/ha) and mean number of fruits/kg attained under T1 to T7 are depicted in Fig 6.

Table 5. Fruit yield (kg/plant), fruit yield per hectare (t/ha) and number of fruits/kg in different treatments tomato crop at Agrahara

Treatments	Fruit yield (kg/plant)	Fruit yield (t/ha)	Mean number of fruits/kg
T1	7	92.29	13.7
T2	6	80.82	13.0
T3	7	94.59	13.0
T4	7	99.19	13.7
T5	7	90.00	11.7
T6	6	77.25	12.0
T7	8	112.50	11.0
Minimum	6	77.25	11.0
Maximum	8	112.50	13.7
Mean	6.86	92.38	12.6
SD	0.69	11.72	1.0
CV (%)	10.1	12.7	8.2
SEM (±)	0.081	1.376	0.859
CD (5%)	0.251	4.24	NS

SD : Standard deviation CV : Coefficient of variation SEM : Standard error of mean
CD : Critical difference NS : Not significant

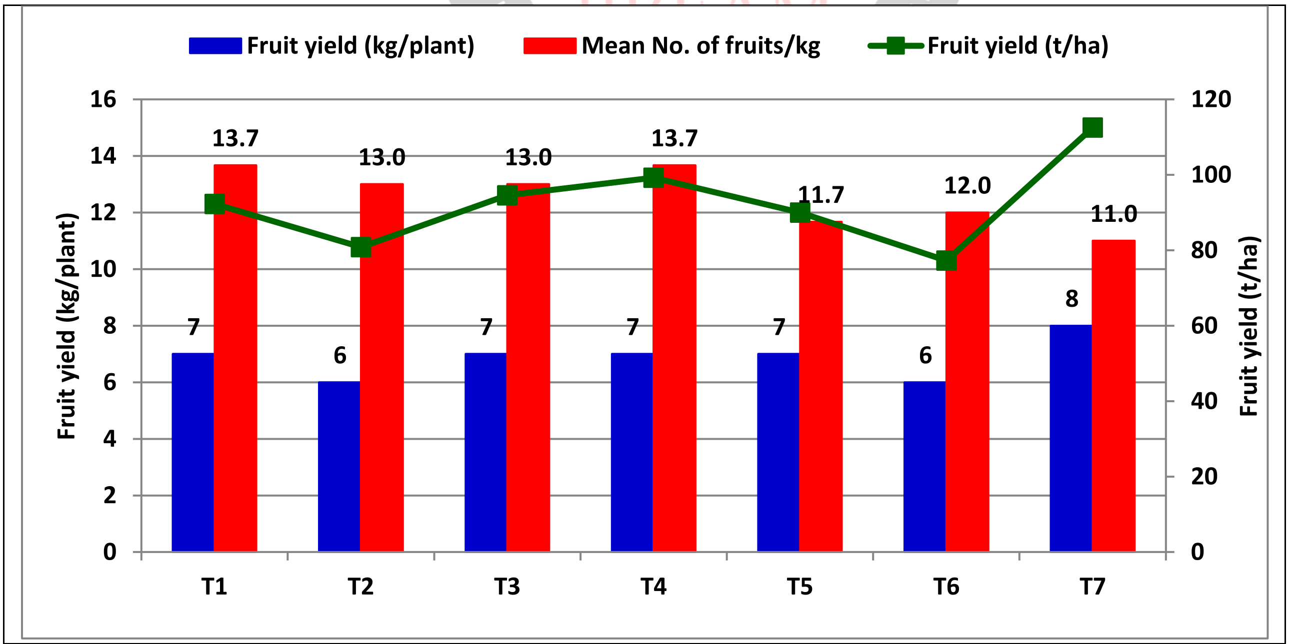

Fig 6. Effect of treatments on fruit yield in tomato crop in Agrahara

An increasing trend was observed at both vegetative and reproductive stages of tomato crop in Agrahara village based on the study. This trend was mainly due to the presence of sufficient moisture and plant nutrients in the available ionic form under the mulched condition along with the drip irrigation.

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Number of fruits per kilogram

The tomato fruits harvested from different treatments T1 to T7 on the final day of harvest were subjected to weighing, in order to know about the number of fruits per kilogram. There was a variation in the total number of fruits per kilogram in different treatments. The variation was mainly due to the imbibitions of the soluble nutrients from soil and water content. Higher the number of fruits would lower the fruit contents, while lesser the number of fruits would enhance the fruit contents. The treatment which received minimum essential cultural practices and integrated nutrient management (INM) has provided the lowest number of 10 fruits, while control treatment (T1) has provided the highest number of 15 fruits (Fig 7).

Fig 7. Total number of fruits per kilogram

Number of roots and Root length

During final harvest and crop senescence stage, root system and depth of main root and its laterals were analyzed to assess nutrient removal from different soil horizons. Deep root system indicated about porous and well-drained nature of soil with good porosity. Higher porosity would lower bulk density. This promotes better root penetration and drag nutrients and moisture from lower layers of root rhizosphere region. Number of roots/plant ranged from 13.33 in T5 to 16 in T2 with mean of 14.76 (CV of 6.6%). Root length ranged from 27.53 cm in T4 to 37.63 cm in T7 with mean of 30.99 cm (CV of 10.7%). Based on ANOVA, the treatments did not differ significantly in influencing number of roots/plant and mean toot length. The number of roots per plant and mean root length (cm) observed in different treatments T1 to T7, along with the descriptive statistics and critical difference values at 5% level of significance for comparing the difference between treatments are given in Table 6. The effect of different treatments on the number of roots per plant and the mean root length in tomato crop are depicted in Fig 8. A comparison of number of roots and root length observed in T1 and T7 is depicted in Fig 9.

Table 6. Total numbers of roots per plant and mean root length observed in different treatments

Treatments	Number of roots per plant	Mean root length (cm)
T1	14.67	28.73
T2	16.00	30.60
T3	13.67	31.60
T4	15.00	27.53
T5	13.33	29.03
T6	15.00	31.80
T7	15.67	37.63
Minimum	13.33	27.53
Maximum	16.00	37.63
Mean	14.76	30.99
SD	0.98	3.32
CV (%)	6.6	10.7
Sem (±)	0.926	1.10
CD (5%)	NS	NS

SD : Standard deviation CV : Coefficient of variation SEM : Standard error of mean
CD : Critical difference NS : Not significant

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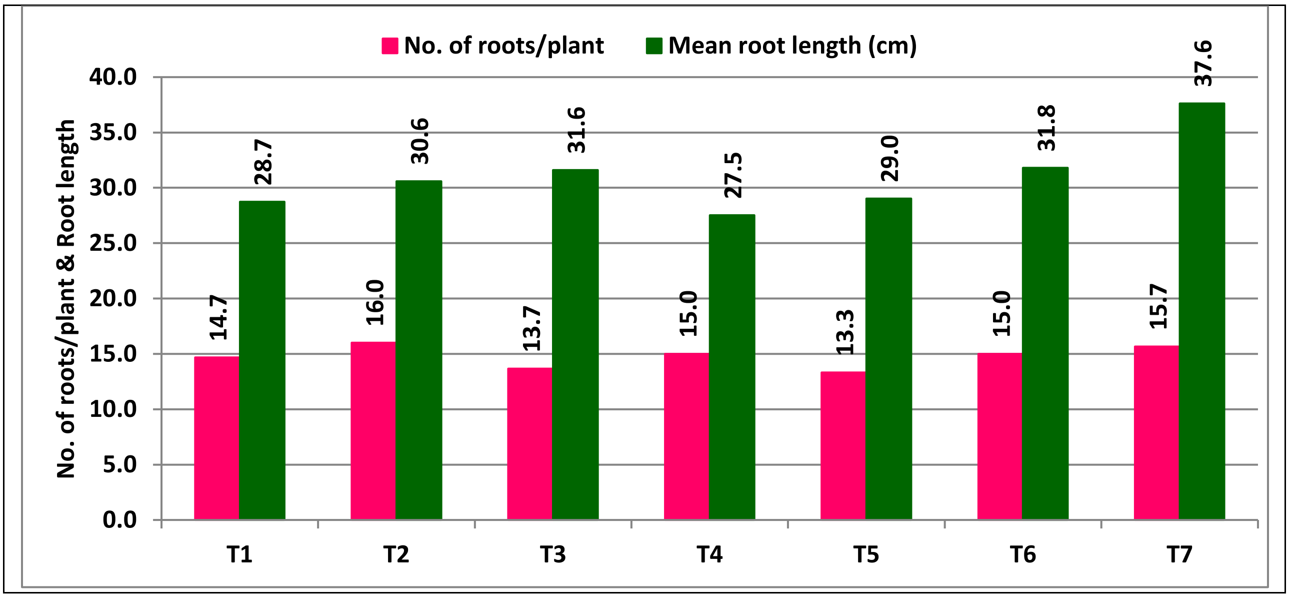

Fig 8. Effect of treatments on number of roots and root length in tomato crop in Agrahara

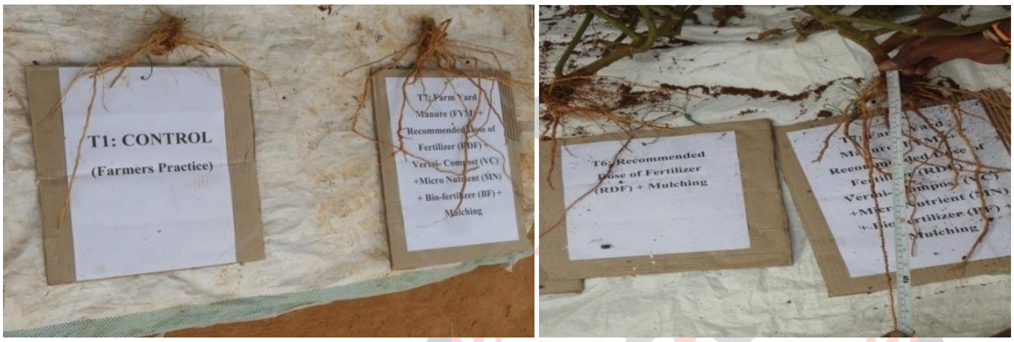

Fig 9. Total number of roots and root length in T1 and T7

The study confirmed that with pre-soil testing and optimum FYM (15 t/acre) as blanket application before transplanting, selection of optimum aged (22-24 days old) seedlings with recommended spacing (3 ft X 1.5 ft) and application of 50 percent N and full dose of P and K gave highest plant establishment and optimum plant population in field. Application of 100 kg of neem cake, installing yellow traps instead of planting marigold, two sprays of 4% Neem Seed Kernel Extract (NSKE) and use of optimum number of irrigations based on soil moisture percent, crop water requirement and stage of crop development would be highly profitable. Fruit weight (g), number of fruits/plant, fruit yield (kg/plant) and fruit yield (t/ha) were on-par with production trials. Growth indices of number and weight of tomato fruits indicated that there is a significant increasing trend from vegetative to maturity stage. Maximum of 15 fruits/kg were attained under T1 compared to 10 fruits/kg under T7. This indicated possibility of sustainable production of tomatoes using recommended package of practices. In T1, excess application of synthetics will lead to higher depletion and lower fruit weight, and hence more number fruits were attained. In T7 with higher dose through organic sources and minimum synthetics, accumulation of organic minerals has lead to more weight of fruits and lower number of fruits/kg. There was a variation in number of fruits/kg in different treatments. Variation was due to imbibitions of soluble nutrients from soil and water content. Higher number of fruits would lower the fruit content, while lower number of fruits would enhance the fruit content.

Soil microbial biomass

Practical and general procedures of natural status of any soil would be microbial biomass (Jenkinson, 1988). It plays a key role in soil nutrient transformation, apart from controlling C:N ratio in addition to other nutrient cycles. Microbial activity was influenced by type of vegetation, substrate availability and abiotic factors. Soil microbial biomass varied significantly among treatments at different stages. Increase in soil microbial biomass (3669 micrograms) was observed in T7 which received more organics along with vermicompost and RDF. Biomass in T6 which received FYM together with vermicompost and no RDF was on-par (3565 micrograms) with T7 (Fig 14). Significantly lower soil microbial biomass was observed in treatment which received no organic manures. T1 gave 38 percent of best treatment (1355 micrograms) based on the study. A comparison of soil microbial biomass observed in different treatments are depicted in Fig 10.

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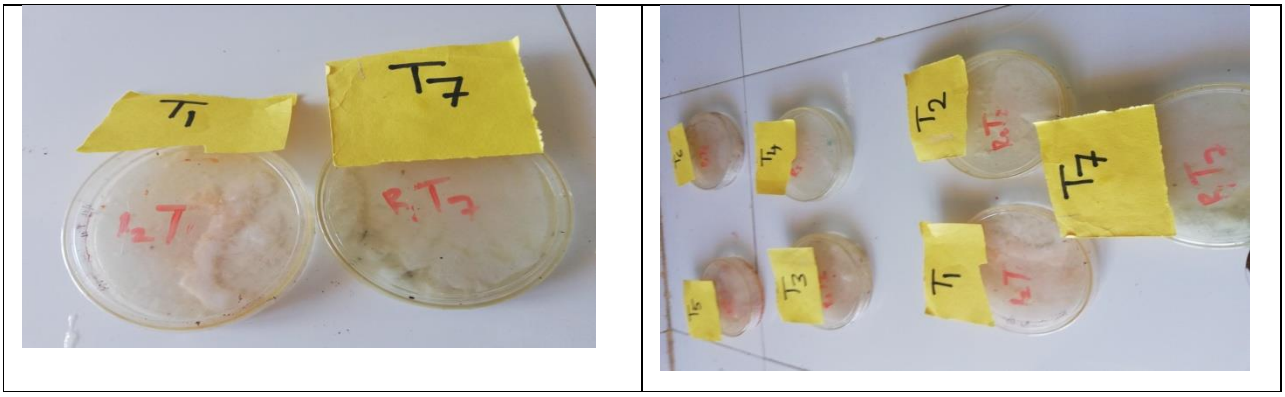

Fig 10. Soil microbial biomass in seven treatments tested in Agrahara

Analysis of cost of cultivation and monetary returns in tomato crop

The details of agri-inputs used and monetary returns attained in the experiment on tomato crop conducted at Agrahara village are given in Table 7. An amount of Rs.82390/- was incurred as cost of cultivation for different inputs and agricultural operations in the study. The cost of cultivation of tomato comprised of Rs.3000/- for ploughing (charges for 4 hours); Rs.5555/- for 5555 seedlings; Rs.8750/- for FYM (12.5 t @ Rs.700/t); Rs.4500/- for pangamia & neem cake (250 kg @Rs.18/kg); Rs.7875/- for synthetic fertilizers (375 kg @Rs.21/kg); Rs.15400/- for plant protection chemicals (28 liters @Rs.540/liter); Rs.10500/- for staking sticks/stumps (for 1750 stumps @Rs.6/stump); Rs.1600/- for steel wires (20 kg @Rs.80/kg); Rs.960/- for gunny rope (32 kg @Rs.30/kg); Rs.9000/- for vermicompost (for 3 acres @Rs.3000/acre); Rs.400/- for zinc sulphate & magnesium sulphate (5 kg each@Rs.40/kg); Rs.75/- for biofertilizers (2.5 kg @Rs.30/kg); Rs.4200/- for 30 irrigations (@140/irrigation); Rs.2500/- for black polythene sheet (25 kg @Rs.90/kg); Rs.875/- for drip mains, laterals & inlets (350 meters @Rs.2.5/m); Rs.7200/- for 32 labour (24 women+8 men).

An amount of Rs.306000/- was attained as gross returns based on tomato yield of 45000 kg attained in the experiment and with a market price of Rs.6.80 per kg of tomatoes. Thus there was a net returns of Rs.223610/- based on the study. The study gave a benefit-cost ratio of 3.71 from the tomato cultivation in Agrahara village. It was found to be significantly higher and economically viable with the adoption of package of practices in tomato crop cultivation. Further, the two relay crops viz., cowpea and ridge gourd were cultivated in the study. With limited number of 4 irrigations to cowpea and 8 irrigations for ridge gourd, an additional income of Rs.4845 and Rs.29910 was attained with benefit : cost ratios of 2.31 and 4.55 with cowpea and ridge gourd crops respectively. The study indicated that by adopting recommended Package of Practices, farmers could attain maximum yield and monetary returns with high BC ratio by growing tomato crop along with relay crops of cowpea and ridge gourd with minimum number of irrigations.

Table 7. Details of agri-inputs used and monetary returns attained in the experiment in Agrahara

Sno	Type of inputs	Quantity	Unit cost (Rs)	Cost (Rs/acre)
1	Ploughing charges for 4 hours (Tractor cultivation)	1 acre	Rs.750/hour	3000
2	Tomato seedlings (Abinava variety)	5555	Rs.1/seedling	5555
3	Farm Yard Manure (t/acre)	12.5	700	8750
4	Pangamia & neem cake (kg/acre)	250	18	4500
5	Synthetic fertilizers (kg/ha)	375	21	7875
6	Plant protection chemicals (litres)	28	550	15400
7	Staking sticks/stumps (No.)	1750	6	10500
8	Steel wires (kg)	20	80	1600
9	Gunny twine/rope (kg)	32	30	960
10	Vermicompost (kg/acre)	3000	3	9000
11	ZnSo4 & MgSo4 (kg)	5 each	40	400
12	Bio-fertilizers (kg)	2.5	42	75
13	Irrigations (No.)	30	140	4200
14	Black polythene sheet (kg)	25	90	2500
15	Drip mains, laterals & inlets (meters)	350	2.5	875
16	Labour (No.)	32 (24 women & 8 men)	Rs.200 (woman) Rs.300 (man)	7200
17	Total cost (Rs.)			82390

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18	Total harvested fruit yield (kg)	45000 kg	6.8	306000
19	Total cost of cultivation (Rs.)			82390
20	Net returns (Rs.)			223610
21	Benefit : Cost ratio			1 : 3.71

Before final harvest of tomato crop, two relay crops of cowpea and ridge gourd were grown without land preparation and application of synthetic fertilizers. The practice of raising a second crop before harvesting main crop is called relay cropping. Two short duration relay crops of cowpea and ridge gourd were grown. Substantial yields and monetary returns were attained from relay crops with minimum investment.

Cowpea (*Vigna unguiculate*) was taken up at 120 days after tomato planting. Seeds of cowpea (S-411) were sown in between tomato plants at 2 ft x 2 ft spacing. After germination, liquid fertilizers and irrigation along with tying of veins to fixed wooden pole were provided. After 45 days of sowing (DAS), runners were initiated for flowering and pod formation. During 7th week, green pods were harvested, which continued upto 11th week. Green pod yield ranged from 98.5 kg/acre (or 244.28 kg/ha) in 11th week to 778.6 kg/acre (or 1930.92 kg/ha) in 8th week. Total yield was 1711.1 kg/acre (or 4243.51 kg/ha) during 7th to 11th week. Cost of seed was Rs.350/acre, 4 irrigations was Rs.560/acre, labour was Rs.1800/acre and top-dressing was Rs.1000/acre. Cost of cultivation of cowpea was Rs.3710/acre. Price of green pods was Rs.5/kg. Gross returns of Rs.8555/acre and net returns of Rs.4845/acre with BC ratio of 2.31 were attained. The harvesting continued for some more weeks and the total green pods yield harvested in different weeks have been recorded and are given in Table 8. The relay crop of cowpea is depicted in Fig 11. The yield and monetary returns attained from cowpea as a relay crop are depicted in Fig 12.

Table 8. Green pod yield of cowpea as a relay crop in tomato in Agrahara

Sno	Growth stage	Green pod yield (kg/ac)	Yield (kg/ha)	Cost of cultivation (Rs/acre)
1	7th Week	185.4	459.79	Seed : Rs.350
2	8th Week	778.6	1930.92	Four irrigations : Rs.560
3	9th Week	519.0	1287.12	Labour : Rs.1800
4	10th Week	129.6	321.40	Top dressing : Rs.1000
5	11th Week	98.5	244.28	Total cost : Rs.3710
Total		1711.1	4243.51	Price per kg (Greens) : Rs.5
Gross returns (Rs/acre)				Rs.8555
Cost of cultivation (Rs/acre)				Rs.3710
Net returns (Rs/acre)				Rs.4845
B:C ratio				1 : 2.31

Sowing of Ridge gourd (*Luffa acutangula*) was taken up at 120 days after tomato planting with seeds of ridge gourd in between tomato plants at 2.5 ft x 2.5 ft spacing. After germination, liquid fertilizers and irrigation along with tying of veins to fixed wooden pole were provided. After 55 DAS, runners were initiated and flowering and pod formation started. During 8th week, green fingerlings were harvested, which continued upto 13th week. Green fingerlings yield ranged from 454 kg/acre (or 1135 kg/ha) in 13th week to 2488 kg/acre (or 6220 kg/ha) in 9th week. Total yield was 7436 kg/acre (or 18590 kg/ha) during 8th to 13th week. Cost of seed was Rs.650/acre, 8 irrigations was Rs.1120/acre, labour was Rs.2400/acre and top-dressing was Rs.4000/acre. Cost of cultivation of ridge gourd was Rs.8170/acre. Price of green fingerlings was Rs.5/kg. Gross returns of Rs.37180/acre and net returns of Rs.29010/acre with BC ratio of 4.55 were attained. The harvesting continued for more weeks and the total green fingerlings harvested in different weeks are described in Table 9. The relay crop of ridge gourd is depicted in Fig 11. The yield and monetary returns attained from ridge gourd as a relay crop are depicted in Fig 12.

Table 9. Green fingerlings yield of ridge gourd as a relay crop in tomato in Agrahara

Sno	Growth stage	Green fingerlings yield (kg/ac)	Yield (kg/ha)	Cost of cultivation (Rs/acre)
1	8th Week	572	1318	Seed : Rs.650
2	9th Week	2488	6220	Eight irrigations : Rs.1120
3	10th Week	2052	5130	Labour : Rs.2400
4	11th Week	1050	2625	Top dressing : Rs.4000
5	12th Week	865	2163	Total cost : Rs.8170
6	13th Week	454	11135	Price per kg (Greens) : Rs.5
	Total	7436	18590	
	Gross returns (Rs/acre)			Rs.37180
	Cost of cultivation (Rs/acre)			Rs.8170
	Net returns (Rs/acre)			Rs.29010
	B:C ratio			1 : 4.55

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Relay crop-1 Cowpea **Relay crop-2 Ridge gourd**

Fig 11. Relay crops of cowpea and ridge gourd grown before harvest of tomato

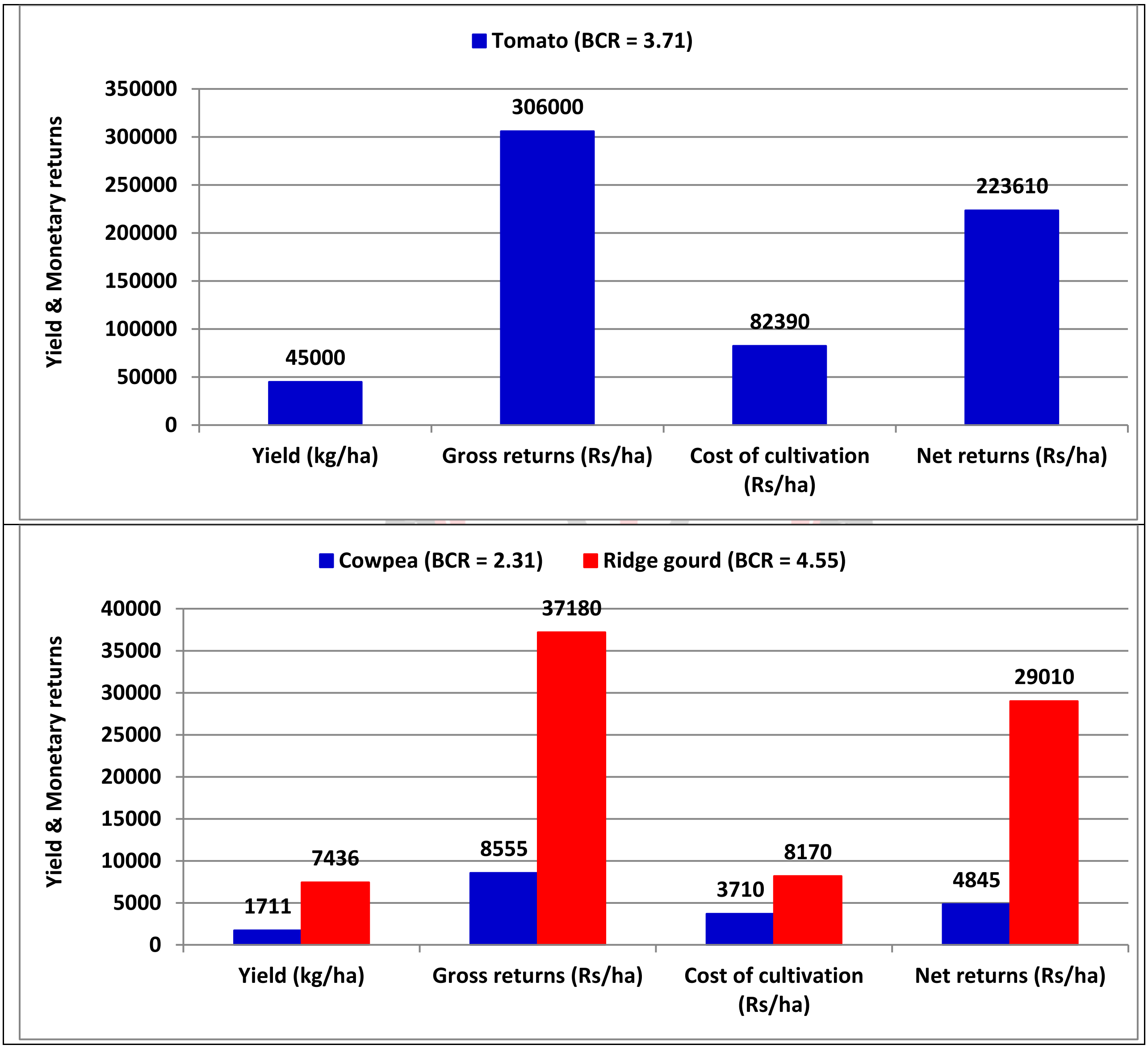

Fig 12. Yield and monetary returns from main crop of tomato and relay crops of cowpea and ridge gourd in Agrahara

Need for adoption of package of practices for attaining maximum yield and monetary returns from tomato crop

Soil testing: Basis of scientific cultivation is conducting soil testing before taking up cropping activity. It is a pre-requisite to operate on-farm with farming practices based on soil test results for efficient nutrient management. Farmers who cultivate tomato would be disturbing soil health by applying excess chemical fertilizers, apart from destroying earthworm population in soil. Soil testing would serve as road map for assessing soil suitability as well as physical, chemical and biological properties, pH, organic carbon content, soil residual nutrients, electrical conductivity and other properties. Tomato yield of 35-40 t/ha would remove about 147.8 kg/ha of N, 19.8 kg/ha of P and 186.2 kg/ha of K. Application of N, P and K is

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important and their prescription must be based on soil test values. Nutrition management is a cost-intensive cultural practice and constitutes about 46% of total cost of cultivation. Growing crops without soil testing leads to many problems of soil fertility and health viz., imbalance in soil nutrition status; poor soil fertility of micro and macro nutrients; poor soil hygiene; accumulation of heavy metals; low crop yield; water logging; and crop loss.

Transplanting bed preparation: Recommended practice for transplanting bed preparation is 2 times ploughing and 1 time harrowing. Textural soil class is red clay and clay loam soils which causes compactness in root rhizosphere region since clay particles are heavier and lead to water logging due to low water infiltration. Excess and repeated ploughing of soil would make it powdery, leading to clay particles settling down at the bottom of soil. This would clog natural drainage of the land leading to water clogging, form hardpan and make the top layer highly susceptible to erosion. Repeated ploughing would lead to destruction of various species of earthworms and beneficial microbes in soil.

Maintaining optimum plant population: Recommended package of practices regarding optimum plant population per unit area is based on intra and inter-row spacing. Recommended spacing is 3 ft X 1.5 ft with plant population of 9990 plants/acre. Due to non-practice of row-to-row and plant-to-plant spacing and adopting narrow spacing (less than recommended), maximum number of plants would be accommodated. This creates competition for light, water and nutrients. The dense plant population gives scope for change in micro-climate of plant canopy, apart from developing symptoms of pest and diseases. In order to efficiently manage the pest and diseases, spray of plant protection chemicals would become important. Cost of cultivation will increase due to increase of pest and disease resistance in the ecosystem. Similar results were observed by [6]. Lower or insufficient number of plants would lead to significantly lower yield. Gap in both intra and inter rows would promote growth of monocot and dicot weeds. Management of weeds would add to total cost of cultivation and become uneconomical. From sustainable productivity point of view, maintenance of optimum plant population per unit area is desired.

Application of oiled neem cake, green manure, and chemical fertilizers: Application of neem cake to vegetable growing fields is recommended since neem cake contains azaradictin plant hormone which inhibits the growth of disease causing fungal and bacterial colony and root–knot, root gall disease causing nematodes population in soil. This is a good sign for protection of soil infestation. This practice would significantly contribute to enhance sustainability and fertility of a soil. Applying neem cake would control soil infestation to a great extent, apart from replenishing soil. Similar impacts were reported and results are in conformity with findings made by [13] neem cake would act as soil antiseptic.

With regard to application of green manure based fertilizers, farmers are not practicing in their fields. It is a highly threatening aspect in tomato cultivation with respect to loss of soil organic carbon. Lower the organic carbon, higher the rate of soil susceptibility in terms of soil erosion and poor soil fertility. Low fertile soils need external feeding with synthetic chemical fertilizers. With application of fertilizers, soil would lose its native fauna and flora and not support the growing plant population. This would result in a steady decline of crop yield. In order to overcome these issues, application of green manures would systematically build desired soil physical, chemical and biological properties over years. Green manures would de-toxify the soil and aids in the buildup of soil-beneficial microbial load and atmospheric N fixation. Continuous practice of green manuring would significantly add organic matter to soil and increase organic carbon. This is in conformity with findings made by [49].

With regard to chemical fertilizers, recommended dose is 100 kg N, 100 kg P and 100 kg K/acre. Farmers require thorough knowledge/proper training on nutrition management. They should be convinced about implications of excess application or wastage of applied nutrients during the stage when crop exhausted all nutrients. Excess application would lead to wastage of fertilizers and destroy soil physical, chemical and biological properties. More than optimum level, excess fertilizer application would be uneconomical and enhance cost of cultivation.

Continuous use of water-soluble fertilizers through drip irrigation would lead to release of non-dissolvable anions and cations into soil parent material. Possibility of accumulation of indissoluble ions and formation of problematic soils is high. Formation of white patches near edge of each row of tomato crop was documented, which was due to application of excess water soluble fertilizers. These un-dissolved salts (both anions & cations) are subject to percolation and seepage in the region where it receives high rainfall. Continuous use of water soluble fertilizers in vegetable crops would cause soil degradation. There is an urgent need for training of farmers with regard to soil management practices which are nature friendly and enhance soil productivity. The results are in conformity with findings of [34] and [48].

Application of weedicides: Recommended dose of weedicide is alachlor @ 0.6 g/liter and butachlor @ 0.6 g/liter of water as pre-emergent dose. Farmers use metribuzin as pre-emergent and post-emergent dose at higher dose of 1 ml/litre. Continuous use of this level would lead to accumulation of residues of herbicide in soil, which would contaminate the water bodies and cause irreparable damage to the aquatic ecosystem. Sensitization of farmers

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on ill effects of use of higher dose of herbicides should be done.

Application of plant protection chemicals: Application of plant protection chemicals includes insecticides and fungicides. Higher the fungicide dose, faster would be pest resistance and survival, and application would become uneconomical. Plants become more susceptible to pests and diseases. There may be changes in crop surveillance which would affect the ecosystem. Crop genomic changes would occur in the long run. Repeated and consistent spray would cause accumulation of residuals in plant, soil, water and human ecosystem. Tomato leaf curl viruses are spreading through irrigation water, while infected fields contaminate non-infected fields. The package is scheduled in such a way that cultivation with trap crops would aid to prevent pest infestation by 35-40% and minimize the spray frequency. There is a need to educate farmers on implications due to excess usage of plant protection chemicals.

Number of irrigations: Critical stages for tomato are branching stage (23-30 days after transplanting), flowering stage (40-45 days after transplanting) and fruit setting and development stage (65-70 days after transplanting). After each picking, irrigation once in a week or 10 days is enough since crop has crossed reproductive stage and entering into senescence stage. Post-reproductive stage contains maximum percent of K which will support build-up of resistance against moisture stress. Tomato crop does not require more moisture or water requirement. Farmers were irrigating tomato crop continuously on every alternate day, which makes number of irrigations as 60 or above in each season. Once crop moves to senescence stage, the accumulated photosynthates in the fruit would cause further ripening and conversion of starch content to sugar.

Quantity of water provided per irrigation: Water requirement per plant would depend on stage and season of crop. During younger stage i.e. 2-4 weeks after transplanting, quantity of water per plant may vary from 0.5-1 litre in summer and 0.5-0.75 litre in winter and rainy season. During log phase of plant growth, water requirement would be more, which will increase during flowering and fruiting stages. Total water requirement in these stages may vary from 3.5-4 litres/plant per irrigation.

Frequency of irrigation: The stage of crop and percent of moisture in the root rhyzosphere region is important for irrigation. As per recommendation, frequency of irrigation is weekly once under ridge and furrow method. Once irrigation is provided through drip system with optimum quantity of water, it is not subjected to evaporation, seepage or percolation losses. Farmers do not understand field capacity and soil moisture availability. The mindset of farmers that irrigation should be provided even if moistness is there in soil should be changed.

Duration of irrigation: Majority of farmers provide irrigation for a longer period than required time. Actual irrigation duration with drip in tomato crop would depend on soil type and water flow rate. Finer the soil type with higher water would reduce the duration of irrigation. Continuous cultivation of tomato is causing a heavy threat on groundwater. There is a need to educate farmers about water use.

V. CONCLUSION

- Soil testing serves as road map for assessing soil suitability & physical/chemical/biological properties, pH, OC, soil nutrients, EC etc. NPK application should be based on soil test values.
- Practice of transplanting bed preparation was with 2 times ploughing+1 time harrowing was enough for the cultivation of tomato crop without destructing soil structure.
- With the field experiment conducted in Agrahara with 7 treatments comprising of package of practices of tomato resulted in the superiority of treatments with the higher production of growth and yield parameters.
- Plant population is 9990 plants/acre & spacing is 3 ft X 1.5 ft. it is optimum plant population in the recommended spacing.
- The application weedicides was not practiced in the experiment and the plastic mulch sheet used was served as the weed control agent in the experiment.
- Neem cake application was resulted in the inhibition in the growth of disease causing fungal & bacterial colony & root–knot, root gall disease causing nematodes in soil
- With regard to application of chemical fertilizers, it is observed that among different respondents, about 28.23 percent were applying lower dosage compared to the recommended level, while 37.65 percent of farmers were applying on-par with the recommendation and 34.11 percent were applying more than the recommended level. This indicated that 34.11 percent of the farmers require proper knowledge/training about the need-based nutrition management, apart from the fact that an excess application would be a wastage of nutrients and also uneconomical.
- The practice of application of plant protection chemicals includes insecticides and fungicides. It is observed that with regard to spray of insecticides, about 54.11 percent of the respondents were spraying more than the recommended level. It led to more susceptibility in the crop resistance to pests. In the long-run, natural hardness would be developed.
- Water requirement/plant depends on crop stage & season. During 2-4 weeks after transplanting, quantity of water/plant varies from 0.5-1 litre in summer & 0.5-0.75 litre in winter & rainy seasons. Water requirement

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is about 3.5-4 litres/plant during flowering & fruiting stages

- 24-26 irrigations are optimum for the optimum crop production in tomato through drip irrigation with mulching and irrigations at crop critical stages was most useful and essential.
- Green manures detoxify soil & build-up soil-beneficial microbial load & atmospheric N fixation. They add organic matter & increase soil organic carbon (SOC). It is important for attaining sustainable yield & maintenance of fertility.
- Due to the higher degree of growth of both vegetative and reproductive parameters, it was resulted in 20.0 per cent increase with PoP practice than the control and possibility of two relay crops in the same piece of land.

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