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Efficiency of chemical fertilizers on flowering, yield attributes and economics of tomato (*Solanum lycopersicum* L) crop under open field conditions

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Abstract
A field experiment entitled "Efficiency of chemical fertilizers on flowering, yield attributes and economics of tomato (*Solanum lycopersicum* L.) crop under open field conditions was conducted at Campus for Research and Advanced Studies, Dhablan during 2019. Experiment was laid out in Randomized Block Design and replicated four times. The treatment comprised T_1: control, T_2: 50% RDF (Recommended doses of fertilizers NPK), T_3: 75% RDF, T_4: 100% RDF, T_5: 125% RDF and T_6: 150% RDF. The field experiment was laid out in Randomized Block Design and replicated four times. Earliness to attain days to first flowering (29.91), days to 50% flowering (34.17), days to 50% fruiting (50.95) and maximum number of flower stem^{-1} (27.91) were reported with 125% RDF. Maximum yield contributing attributes i.e. weight of single fruit (70.58 g), fruit diameter (51.52 mm), fruit length (59.30 mm) and fruit yield (188.02 q ha^{-1}) were examined under T_5: 125% RDF which was followed by T_4: 100% RDF and T_6: 150% RDF. The economic attributes like maximum net returns was recorded in T_5: 125% RDF while the B:C ratio (2.67) were recorded best under T_4: 100% RDF. It is thus concluded from the study that 100% RDF was helpful to increase yield and gave more benefits to farmers.

Keywords: tomato, fertilizers, flowering, yield, economics

Introduction
Tomato (*Solanum lycopersicum* L.) is a self- pollinated crop. Tomato was originally named as *Solanum lycopersicum* by Linnaeus in 1973. Miller (1978) in The Garden's Dictionary used as *Lycopersicon esculentum.* For a long time tomatoes were known as *L. esculentum* but recent research has shown that they are part of the genus solanum and are now again broadly referred to as *Solanum lycopersicum* by Peralta and Spooner in 2006. Tomato is known as protective food as it is being extensively grown all over the world both for fresh market and processing. The origin of tomato crop is from Andes region of Peru, Bolivia and Ecuador (George and Stenley, 1983).

In tomato production India ranked second after China. India contributes about 46% to the total world production and occupies an area of 778 thousand hectare in the country with a production of 19397 thousand million tons (NHB, 2019) [25]. Tomato is cooked as a vegetable alone and it is also used as ingredient in all dishes. The chemical composition of tomato fruits includes total sugars 2.5 – 4.5%, reducing sugar 1.5 – 3.5%, starch 0.6 – 1.2%, Ascorbic acid 15 – 30 mg 100g^{-1}, Vitamin A 833 – 1667 IU 100g^{-1}, Vitamin B_1 15 – 75 mg 100g^{-1}, Vitamin B_2 20 – 80 mg 100g^{-1}, citric acid 450 – 1400 meq 100 g^{-1} and total amino acids 100 – 350 mg 100g^{-1}. In the recent decades, the consumption of tomatoes has been associated with prevention of several diseases mainly due to the content of antioxidants including carotene, lycopene as well as β – carotene and phenolic compounds reported by Wilcox in 2003.

Yield is the main goal to obtain good quality tomato fruits by application of nutrients. In tomato crop basically two types of fertilizer are used i.e. inorganic and organic fertilizer. Nowadays, inorganic fertilizers improve yield and quality of tomato fruit. The tomato crop requires more quantity of nitrogen, phosphorus and potassium for growth and yield of fruit (Naz *et al.* (2012) [24]. For improving the yield of the produce, it is necessary to consider on balanced use of nutrients through fertilizer application. In modern era of agriculture, because of increased levels of NPK fertilizers are important for better nutrient management. More than any other nutrients, nitrogen influence vegetative growth and yield of tomato plant.

Nitrogen is essential for building up protoplasm and protein, which induce cell division and initial meristematic activity when applied in optimum quantity. According to Mukta *et al.* (2015) [22] nitrogen present in the soil increases the quality, fruit size and health of plant. Phosphorus is known to its positive effect on male parts i.e. pollen formation, pollen grain size that is helpful in more number of flowers and fruits. Phosphorus in tomato increases the concentration of K, P, Mg and Fe in the leaves, increase fruit size, yield and quality. The phosphorus increases vegetative growth as well as reproductive growth and it induces earliness in flowering, fruiting and seed formation (Buckman and Brady 1980) [6]. The percentage of unevenly ripened tomatoes and hollow cracked miss-shaped tomato decreases with increased application of potassium. It makes the health and vigor of plant better and also helpful in standing crop against frost and other climatic conditions. The fruit quality is also improved with the help of potassium Kumar *et al.* (2015).

Material Methods

The field experiment was conducted at an experimental farm area of Post Department of Agriculture, Khalsa College, Patiala during 2019 located 31º-38´ N latitude and 74 º-52´ E longitude with an elevation of 236 m MSL and represents the sub-tropical climate and humid zone of Punjab region in order to work efficiency of different chemical fertilizers on tomato crop. The soil of an experimental plot was clayey loam in texture with pH 7.3, organic carbon (0.52%), available nitrogen (262.62 kg ha^{-1}), available phosphorus (22.32 kg ha^{-1}) and potassium (130.00 kg ha^{-1}). The experiment was laid in a randomized block design with four replications having 6 treatments comprising different doses of inorganic fertilizers *viz*. control (T_1), 50% RDF (T_2), 75% RDF (T_3), 100% RDF (T_4), 125% RDF (T_5), 150% RDF (T_6). Recommended doses of fertilizers (NPK 50:60:60 kg ha^{-1}). The source of nitrogen is urea, phosphorus is single super phosphate and potash source is MOP. The tomato (Hybrid Shiva) seedlings were transplanted at 75*45 cm spacing on 23rd March 2019. All other cultural practices were followed as per standard recommendations. The economics of different cultural practices, input and returns for tomato variety Shiva under each treatment combination was worked out to find the most effective and economical treatment.

The data were analyzed as per the standard procedure for Analysis of Variance (ANOVA). The difference in the treatment mean was tested by using critical difference (CD) at 5% level of probability.

Result and Discussion

Phenological parameters

The data pertaining to days to first flowering have been presented in table 1.1. It is cleared from the data that days to first flowering were showed significantly different results affected by different treatments. The results findings showed that minimum days for first initiation of flowering (29.91 days) was recorded in treatment T_5 (125% RDF) and treatment T_4 (100% RDF) also showed less days to first flowering (30.15) as compared to other treatments. The maximum number of days (36.21 days) taken to first flowering was observed in treatment T_1 (Control). The related days to 50% flowering was showed the significant difference among all the treatments after analysis of variance. The result pertaining with days to 50% flowering revealed that minimum days taken to 50% flowering (34.17 days) were observed in the treatment T_5 i.e. 125% RDF. The maximum days taken for 50% flowering was observed in treatment T_1 i.e. Control (41.64 days). Earlier flower formation helps in the early fruit development and it also help in timely maturation of crop. The data revealed that number of days taken to first flowering are less in T_5 i.e. 125% RDF. The availability of nitrogen and phosphorus has positive effect, especially phosphorus plays a major role in flower bud initiation and formation of flower on it. The present result fulfill the findings of Kumar and Shammungaule in 1978 who find out that higher doses of nitrogen, also promote protein synthesis that help in early floral primordial development. The similar result findings were reported by Dhiman *et al.* (2018) [8], Tiwari *et al.* (2012) [31] and Balemi (2008) [3].

The days to 50% fruiting showed the significant difference with different rates of fertilizers. The minimum days (50.95 days) to 50% fruiting was observed in treatment T_5 i.e. 125% RDF. The other recommended doses of fertilizer also showed good result as compared to control. The highest number of days taken for 50% fruiting was observed in control treatment T_1 i.e. 59.86 days. Nitrogen, phosphorus and potassium help in early vegetative growth, more photosynthetic activities and optimum level of synthesis of cytokines at high level of primary nutrients would have highest result in setting more favorable sink to produce more fruit. It might have produce number of flower and resulted in more fruits per plant because nutrients are available to the plant at critical stages. The hormones like naphthalene acetic acid and auxin plays very crucial role in fruit setting in tomato and the synthesis of these hormones accerlated by these essential nutrients. Similar result findings were also reported Dhiman *et al.* (2018) [8], Aminiford *et al.* (2012) [1], Singh *et al.* (2010) [27], Balemi (2008) [3], Beukma and Vander (1990) [4] and Mulubrahan (2004) [21].

Perusal of data presented in table 1.1 revealed that chemical fertilizers had showed significant effect on number of flowers $stem^{-1}$. The highest number of flowers $stem^{-1}$ (27.91) was found in treatment T_5 i.e. 125% RDF which is statistically at par with T_4: 100% RDF (26.51). Chemical fertilizers has great influence on number of flowers $stem^{-1}$, it was shown that lowest number of flowers $stem^{-1}$ (19.31) was found in treatment T_1 i.e. control where no chemical fertilizers were applied to crop.

Flower is a major yield enhancing component of plant. The number of flower per $stem^{-1}$ was recorded highest in treatment i.e. T_5 i.e. 125% RDF. As we know that plants take up nutrients from soil and utilized soil nutrients for vegetative and reproductive growth. The all primary nutrients like nitrogen, phosphorus and potassium are applied at optimum quantity and it promotes flowering and fruit setting with uniform fruit number. Phosphorus is known for its positive effect on male parts of flower i.e. pollen formation of flower, pollen grain size which is helpful in more number of flowers per plant (Lau and Stephenson 1994 and Jenifer *et al.* 2002) [16]. The number of flowers $stem^{-1}$ was gradually increased up to 60 DAT and after that is started decreasing. It is due to environmental factors that affect flower production. Increased of temperature during May - June effect flowering as studied by Farhad *et al.* 2009 [9]. The present study was in agreement with Shukla *et al.* (2009) [30] Iqbal and Niamatullah in 2011 [15] also stated that increased levels of nitrogen and potassium increases number of flower $plant^{-1}$.

Table 1: Efficiency of different chemical fertilizers on flowering parameters of tomato

Treatment	Days to first flowering	Days to 50% flowering	Days to 50% fruiting	Number of flowers stem^{-1}
T_1 : Control	36.21	41.64	59.86	19.31
T_2 : 50% RDF	34.18	39.21	57.39	21.15
T_3 : 75% RDF	32.74	37.55	55.51	23.63
T_4 : 100% RDF	30.15	36.86	53.61	26.51
T_5 : 125% RDF	29.91	34.17	50.95	27.91
T_6 : 150% RDF	30.77	36.51	52.88	26.32
CD at 0.05	1.99	1.64	2.77	1.58

Recommended doses of fertilizers (NPK 50:60:60 kg ha^{-1})

Yield Parameters

It is evident from the data presented in table 1.2 that different treatment showed significant effect on fruit diameter. The diameter of fruit range varied between 40.76 mm to 51.52 mm. The highest fruit diameter (51.52 mm) was noticed in treatment T_5 i.e. 125% RDF which was followed by T_6: 150% RDF (49.91 mm) and T_4: 100% RDF (49.59). However, minimum diameter of fruit (40.76 mm) was recorded in treatment T_1 i.e. control. The highest fruit length (59.30 mm) was reported in treatment T_5: 125% RDF that was statistically at par with by T_6: 150% RDF (57.77 mm) and T_4: 100% RDF (56.66 mm). Whereas, lowest fruit length (50.20 mm) was recorded in treatment T_1 i.e. control.

The size of fruit is very important for its marketing and consumer preference. The highest fruit diameter and length was examined in T_5 i.e. 125% RDF. The increase in fruit size is due to more supply of fertilizers that could be helpful in more vegetative growth i.e. more foliage, plant canopy and higher supply of photosynthesis. Potassium application significantly increased fruit diameter, because potassium help in activation of enzyme and its involve in adenosine triphosphate (ATP) production which is important in regulating the rate of photosynthesis and enables the plant to store more food in the fruits. Colakoglu (1985) who stated that correlation between fruit size and potassium contents. When potassium content are very low, fruits size are also small but when they are too high fruits are also larger and have thick peel. The combined application of NPK favored the metabolic and auxin activities and ultimately resulted in increased fruit size. These results are in close conformity with the finding of Dhiman *et al.* (2018) [8], Biswas *et al.* (2015) [5], Amjad *et al.* (2014) [2], Iqbal *et al.* (2011) [15] and Havlin *et al.* (2005) [14].

An examination of data showed in table 1.2 that fruit weight was also affected by all treatments as the values obtained were significant. The maximum fruit weight (70.58 g) was obtained in treatment T_5 i.e. 125% RDF which was statistically at par with (68.12 g) T_6 i.e. 150% RDF and T_4: 100% RDF (68.06). However, minimum fruit weight (60.36 g) was observed in treatment control (T_1).

The weight of fruit is the third most important yield contributing component of fruit yield. The maximum fruit weight was noticed in T_5 i.e. 125% RDF. It was cleared that increased fruit weight might be due to better utilization of photosynthesis and increased more photosyntate to economics parts. The application of more doses of phosphorus and potassium are helpful in more fruit weight a by increasing translocation of photosynthates to fruit and more water use efficiency. Whereas, according to present study higher doses of nutrients starts decreasing fruit weight because nutrient concentration moving towards toxicity level. These findings are closely related with the investigation of Biswas *et al.* (2015) [5], Pervez *et al.* (2013) [26], Naryan *et al.* (2011), Iqbal *et al.* (2011) [15], Gill *et al.* (2018) [12], Balemi (2008) [3] and Sharma and Arora (1987) [29].

It is apparent from the data presented in table 1.2 revealed that maximum fruit yield (188.02 q ha^{-1}) was noticed in T_5 i.e.125% RDF which was statistically at par with T_6: 150% RDF and T_4: 100% RDF. On the other hand, minimum fruit yield (133.33 q ha^{-1}) was recorded in T_1: control.

Yield of tomato fruit is a dependent character that is affected by plant height, number of branches plant^{-1}, number of fruits and fruit weight. The yield is mainly depending on soil nutrient status but it also depends on genetic makeup of varieties. However, the nutrients status of soil is also helpful in more yields. In the current study, the higher yield in tomato fertilized with higher doses of nitrogen, phosphorus and potassium was recorded in 125% RDF. The application of more doses of fertilizers increased tomato yield but if applied fertilizers in large quantities like where 150% RDF was applied it showed not significant result because more doses of nutrients showed imbalance of nutrients in soil which ultimately started decreased yield. The increase in yield of tomato is due to greater availability of nutrients like nitrogen, phosphorus and potassium, resulting in maximum photosynthesis and enhanced food accumulation in edible parts. However, potassium does not play role in yield of plant directly but indirectly it plays role in yield, which are supported by past studies undertaken by Majumdar *et al.* (2000) [20], Kooner and Randhawa *et al.* (1990). Many researchers confirmed that yield depends to the NPK fertilizer rates. These results are in accordance with those Biswas *et al.* (2015) [5], Naryan *et al.* (2011), Sonste *et al.* (2009), Sanju *et al.* (2010) and Gonzalez *et al.* (2012) [13] of who were also stated that increase in the fertility level produced more fruit yield (t ha^{-1}).

Table 2: Efficiency of different chemical fertilizers on yield attributes of tomato

Treatment	Fruit diameter (mm)	Fruit length (mm)	Weight of single fruit (g)	Fruit Yield (q ha^{-1})
T_1 : Control	40.76	50.20	60.36	133.22
T_2 : 50% RDF	43.17	52.02	63.27	150.38
T_3 : 75% RDF	45.11	53.56	65.4	165.60
T_4 : 100% RDF	49.59	56.66	68.06	185.60
T_5 : 125% RDF	51.52	59.30	70.58	188.02
T_6 : 150% RDF	49.91	57.77	68.12	187.56
CD at 0.05	1.98	2.80	2.58	5.44

Recommended doses of fertilizers (NPK 50:60:60 kg ha^{-1})

Economics of tomato

There was significant effect of different doses of chemical fertilizers on economics. Economic analysis was done to compare the cost and benefits ration of different treatments. For this purpose, the input cost for field management, seedlings, transplanting, fertilizers applications and intercultural operations and weeding required for all the operations were recorded against each treatment combinations, which were then calculated into cost ha^{-1}. The data regarding economics is presented in Table 1.3.

The data clearly showed that the maximum gross return (Rs. 188020 ha^{-1}) was obtained in the treatment T_5: 125% RDF. On the other hand, the minimum gross return (Rs. 133220 ha^{-1}) was reported with the treatment T_1: Control. It was clearly indicated that the highest net return

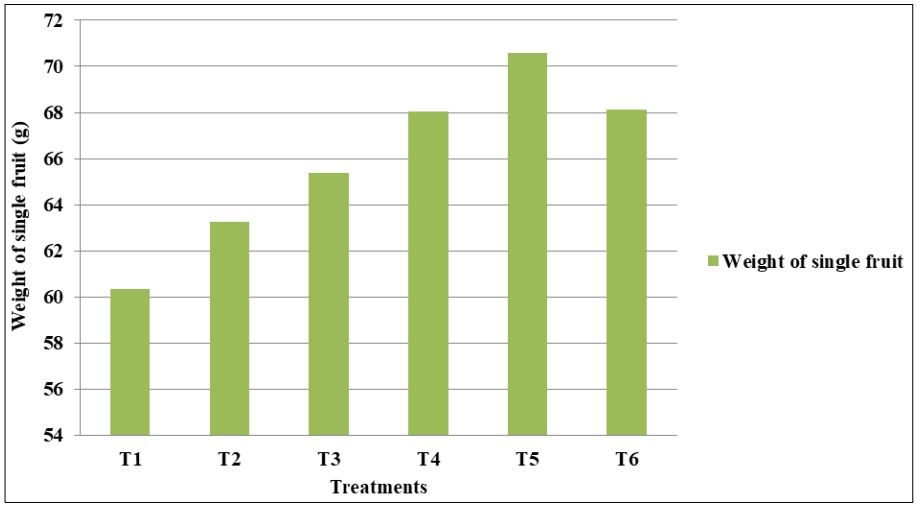

Fig 1: Efficiency of different chemical fertilizers on weight of single fruit of tomato

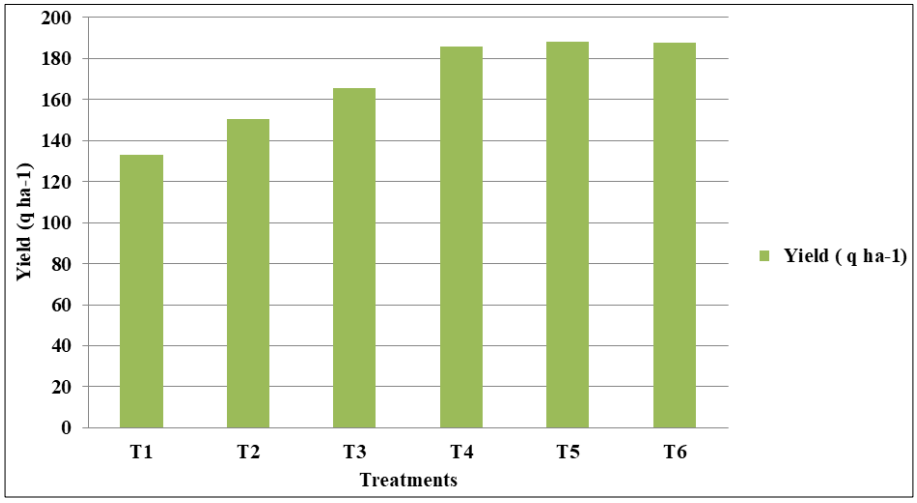

Fig 2: Efficiency of different chemical fertilizers on fruit yield (q ha^{-1}) of tomato

(Rs. 136194 ha^{-1}) was reported under treatment T_5: 125% RDF. On the other hand, lowest net return (Rs. 87720 ha^{-1}) was noticed under T_1: control. Whereas, maximum benefit cost ratio (B:C) (2.67) was recorded in treatment T_4: 100% RDF. With increasing levels of fertilizer from 100% to 150% yield don't increase significantly but it increases the cost of cultivation and lowers the benefits and effect B:C ratio. On the other hand, lowest B:C ratio (1.92) was recorded under T_1: control.

Table 3: Effect of different chemical fertilizers on gross return, net return and benefit cost ratio of tomato crop

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
T_1 : Control	45500	133220	87720	1.92
T_2 : 50% RDF	48029	150380	102351	2.12
T_3 : 75% RDF	49309	165720	116411	2.36
T_4 : 100% RDF	50565	185607	135042	2.67
T_5 : 125% RDF	51826	188020	136194	2.62
T_6 : 150% RDF	53094	187569	134476	2.53
CD at 0.05		5454.85	5454.85	0.13

Recommended doses of fertilizers (NPK 50:60:60 kg ha^{-1})

Conclusion

On the basis of current study we concluded that flowering and yield attributes like number of flowers stem^{-1}, fruit length, diameter, fruit weight, yield and quality of fruit was recorded which 125% RDF which was statistically at par with 100% RDF and 150% RDF. While, maximum B:C ratio was recorded with 100% RDF. From the present investigation, it was concluded that the treatment 100% RDF recommended for the farmers because its benefit cost ratio was maximum and also have a good response in getting higher yield of tomato crop.

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