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Impact of integrated nutrient management on growth parameters of pomegranate (*Punica granatum* L.) cv. Bhagwa

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Abstract
An experiment was conducted to know the impact of integrated nutrient management on growth parameters of pomegranate (*Punica granatum* L.) cv. Bhagwa at farmer's field, Bagepalli taluk, Chikkaballapur district. The experiment was laid out in a randomized complete block design with three replications and twelve treatments. The results indicated that, the growth parameters such as plant height, stem girth, number of stems per plant, plant spread (N-S and E-W), number of shoots, shoot length, shoot girth, number of leaves per shoot and leaf area were significantly higher in a plants treated with 100 per cent RDF + vermicompost (5kg/plant) + neem cake (1kg/plant) + trichokawach (100g/plant) + darakshak (4ml/litre) foliar application + VAM (50g/plant) + *Penicillium pinophilum* (20g/plant) + seaweed extract (20g/plant) + chitosan (2g/litre) + salicylic acid (300ppm) + phosphoric acid (3ml/litre) + micronutrients through soil and foliar application + growth regulators (foliar application). Hence, it indicated that, treatment (T_{12}) enhances the growth parameters which indirectly improves the flowering and yielding capacity of pomegranate plants.

Keywords: Bio-stimulants, bio-fertilizers, growth parameters and pomegranate

1. Introduction

Pomegranate (*Punica granatum* L.) is one of the oldest known domesticated edible fruit regarded as 'Fruit of paradise'. It belongs to a distinct family Lythraceae and having a chromosomal number 2n=16 (Rana *et al.*, 2010) [16]. The fruits are mainly valued for its economic, nutritional, industrial, pharmaceutical and medicinal values, also for domestic and export purpose. The crop is commercially cultivated for its versatile adaptability, hardy nature, tolerance to salinity and drought, low maintenance cost and high remunerative nature (Hussain *et al.*, 2017) [7]. India is one of the leading producer of pomegranate in the world covering an area of about 2.83 lakh hectare with an annual production of 31.86 lakh tonnes and productivity of 12.60 tonnes per hectare (Anon., 2018) [1]. Despite of huge production of pomegranate in India, but the productivity and per cent export shares from India goes relatively less and in small volume. One of the key reasons behind low productivity and poor quality fruits is inadequate nutrition, indiscriminate use of chemical fertilizers (imbalance use of nutrients) and negligence towards the use of organic and bio-fertilizers leading to the chemical toxicity and higher susceptibility to disease infection (bacterial blight and fungal diseases) and pest attacks (aphids and fruit sucking moth) (Thanari and Suma, 2018) [18].

Hence there is a need for viable, eco-friendly and cost effective technique to mitigate these problems (Lalithya *et al.*, 2017) [12] and one such approach is integrated nutrient management (INM). Therefore, by combined application of organic manures, inorganic fertilizers, bio-fertilizers, bio-stimulants and growth regulators in a judicious manner will helps to maintain soil fertility by enhancing the crop productivity and quality with reduction in diseases incidence (Bacterial blight) as well as possible reduction of chemical inputs which is the main essence of integrated nutrient management (INM). Considering the importance of INM aspects and to formulate a holistic technology for pomegranate, an experiment was been carried out, entitled on "Impact of integrated nutrient management on growth parameters of pomegranate (*Punica granatum* L.) cv. Bhagwa".

2. Materials and Methods

2.1 Experimental location

An experiment entitled "Impact of integrated nutrient management on growth parameters of pomegranate (*Punica granatum* L.) cv. Bhagwa" was undertaken during 2019 to 2021. The research study was carried out at farmer's field, Bagepalli taluk, Chikkaballapur district, Karnataka and the experimental site was located at 13° 78′ North Latitude and 77° 79′ East Longitude with an elevation of 707 metres (2319 ft) above the mean sea level (MSL). The details of the material used and methodologies adopted for the study during the investigation are described below.

2.2 Experimental design and treatments

The experimental design adopted for the experiment was Randomized Complete Block Design (RCBD) consisting of 12 treatments with three replications. Healthy uniform pomegranate plants were selected and treated with different source of organic and inorganic fertilizers in single or in combinations. The details of treatments and fertilizers used in the experiment are mentioned as follows. T_1: 100% RDF through soil application, T_2:75% RDF + Trichokawach (100g/plant) + Darakshak (4ml/litre/plant) Foliar application + VAM (50g/plant) + *Penicillium pinophilum* (20g/plant) + Seaweed extract (20g/plant) + micronutrients (Soil and Foliar application), T_3: T_2 + Growth regulators, T_4: 75% RDF + Chitosan (20g/plant) Soil application + Chitosan (2g/litre/plant) Foliar application + micronutrients (Soil and Foliar application), T_5: 75% RDF + Salicylic acid (10g/plant) Soil application + Salicylic acid (300ppm/plant) Foliar application + micronutrients (Soil and Foliar application), T_6: 75% RDF + Phosphoric acid (20ml/plant) Soil application + Phosphoric acid (3ml/litre/plant) Foliar application + micronutrients (Soil and Foliar application), $T_{7,}$ 9 and 11: (75%, 50% and 100% RDF + Trichokawach (50g/plant) + Darakshak (4ml/litre/plant) Foliar application + VAM (50g/plant) + *Penicillium pinophilum* (20g/plant) + Seaweed extract (20g/plant) + Chitosan (20g/plant) + Salicylic acid (10g/plant) + Phosphoric acid (20ml/plant) + micronutrients through Soil application), $T_{8,\ 10\ \text{and}\ 12}$: (75%, 50% and 100% RDF + Trichokawach (50g/plant) + Darakshak (4ml/litre/plant) Foliar application + VAM (50g/plant) + *Penicillium pinophilum* (20g/plant) + Seaweed extract (20g/plant) + Chitosan (2g/litre/plant) + Salicylic acid (300ppm/plant) + Phosphoric acid (3ml/litre/plant) + micronutrients through Soil and Foliar application). Except treatment T_1 rest were applied with Vermicompost (5kg/plant) + Neem cake (1kg/plant) and growth regulators foliar spray (except T_1 and T_2) in common.

2.3 Imposition of plant stress

To create artificial stress, leaf shedding and proper accumulation of nutrients in different parts of the plant, the irrigation was with holded for 30 to 45 days in pomegranate plants.

2.4 Pruning

Light pruning was done by removing 10 to 15 cm from the tip of shoot with the help of secateurs during the first week of February, 2020 (first year) and 2021 (second year) respectively. All the dead and diseased shoots, suckers and unwanted shoots were removed to facilitate better aeration and to reduce the inoculum load under field condition.

2.5 Ethrel (ethylene) application

To enhance proper and complete leaf shedding, ethrel was sprayed on second week of February, 2020 (first year) and 2021 (second year) respectively.

2.6 Fertilizers application

The recommended dose of fertilizers 625:250:250 ($N:P_2O_5:K_2O$ grams/plant) were applied as per the norms of National Research Centre, Pomegranate, Solapur (Anon., 2016, Anon., 2017 and Gajbhiye *et al.,* 2020) [3, 5]. Urea was applied as four splits; single super phosphate (SSP) and muriate of potash (MOP) were applied as 3 splits doses during growing season (Lalithya *et al.*, 2017) [12]. The fertilizers such as vermicompost (5 kg/plant), neem cake (1 kg/plant), trichokawach (100 g/plant), VAM (Glomus spp) (50 g/plant), *Pencilium phinophilum* (20 g/plant) and seaweed extract (20 g/plant) were applied once through soil application during bahar treatment. The soil application of micronutrients, chitosan (20 g/plant), salicylic acid (10 g/plant) and phosphoric acid (20 ml/plant) were applied twice through split application during bahar treatment and 3 months after the first application.

The foliar application of darakshak (4 ml/litre), micronutrients, chitosan (2 g/litre), salicylic acid (300 ppm) and phosphoric acid (3 ml/litre) were applied twice at pre-flowering stage and at fruit colour green to pink conversion stage. The growth regulators such as lihocin (500 ppm) was applied 20 days after leaf shedding, NAA (50 ppm) was applied 30 days after bahar treatment and gibberellic acid (50 ppm) was applied 120 days after bahar treatment.

2.7 Growth parameters

Five plants were selected from each replication for recording observations in each treatment. All the growth parameters were recorded at monthly intervals from the tagged plants. The growth parameters such as plant height, stem girth, number of stems per plant, plant spread (N-S and E-W), number of shoots, shoot length, shoot girth, number of leaves per shoot and leaf area of pomegranate in response to integrated nutrient management were recorded.

3. Results and Discussion

3.1 Plant height (m)

The plant height recorded a non-significant difference among the treatments at 45 days after plant growth (1.73 to 1.88 cm) during both the consecutive years. However, The INM treatments recorded a significant increment in plant height at 90, 135 and 180 days after plant growth (Table 1). The maximum plant height was recorded in T_{12} (2.09, 2.23 and 2.37 m) while the minimum plant height was noticed in T_1 and T_9 (1.83, 1.96 and 2.05 m) respectively.

The probable reason for the increase in plant height parameter may be attributed due to the combined application of balanced dose of inorganic fertilizers along with organic manures, bio-fertilizers and bio-stimulants have led to improve the physical, chemical and biological properties of soil by increasing the soil microbial activity. Improvement in soil parameters might have helped in increasing the absorption of nutrients from the soil at optimum level and enhanced better assimilation of carbohydrates within the plants. The results are in conformity with Kurer *et al.* (2017) [11], Kumar *et al.* (2018) [10] and Kumar *et al.* (2020) [9] in pomegranate.

Table 1: Effect of integrated nutrient management on plant height (m) of pomegranate plants at monthly intervals

Treatments	Plant height (m)											
	Vegetative and flowering stage						Fruiting stage					
	45 days			90 days			135 days			180 days		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1	1.64	1.82	1.73	1.74	1.92	1.83	1.87	2.07	1.97	1.96	2.18	2.07
T_2	1.63	1.92	1.77	1.80	2.11	1.96	1.90	2.18	2.04	2.03	2.28	2.16
T_3	1.65	1.96	1.80	1.82	2.15	1.98	1.98	2.27	2.12	2.10	2.40	2.25
T_4	1.61	1.87	1.74	1.73	2.07	1.90	1.88	2.16	2.02	1.98	2.27	2.13
T_5	1.63	1.91	1.77	1.79	2.04	1.92	1.95	2.19	2.07	2.08	2.32	2.20
T_6	1.60	1.88	1.74	1.76	2.10	1.93	1.90	2.22	2.06	2.06	2.36	2.21
T_7	1.69	1.98	1.83	1.86	2.15	2.00	2.01	2.27	2.14	2.13	2.42	2.27
T_8	1.70	1.94	1.82	1.89	2.19	2.04	2.06	2.34	2.20	2.18	2.47	2.33
T_9	1.64	1.84	1.74	1.71	1.98	1.85	1.82	2.09	1.96	1.90	2.10	2.05
T_{10}	1.66	1.95	1.80	1.75	2.05	1.90	1.85	2.16	2.01	1.93	2.27	2.10
T_{11}	1.73	2.00	1.86	1.92	2.21	2.07	2.10	2.34	2.22	2.21	2.48	2.35
T_{12}	1.74	2.02	1.88	1.95	2.22	2.09	2.13	2.33	2.23	2.24	2.49	2.37
S.Em ±	NS	NS	NS	0.02	0.02	0.03	0.03	0.02	0.03	0.03	0.02	0.03
C. D @5%	NS	NS	NS	0.06	0.06	0.08	0.09	0.06	0.08	0.09	0.06	0.09

3.2 Stem girth (mm) and number of stems per plant

The data recorded with respect to stem girth during vegetative and harvesting stage as affected by INM treatments are presented in Table 2. The highest increase in stem girth at vegetative and harvesting stage was noticed in T_2 (47.88 and 53.18 mm) while the least response towards the increment in stem girth was observed in T_5 (40.70 and 45.65 mm) respectively.

The possible reason for the increase in stem girth of plant treated with T_2 might be due to the beneficial effect of combined application of bio-fertilizers along with inorganic fertilizers through RDF and foliar application bio-stimulants and micronutrients has increased the availability of major nutrients in the soil which in turn promotes cell elongation, cell division and growth hormone activity within the plant system. Hence, these factors resulted in increasing the girth growth, by enhancing biomass accumulation and carbohydrates production. Similar results were also observed by Virginio (2020) [19] in pomegranate.

3.3 Plant spread (North-South and East-West) (m)

The data related to plant spread (N-S and E-W) is furnished in Table 3 and 4. While, INM treatments significantly enhanced the plant spread during both the years of experiment. The plant spread (N-S and E-W) displayed a significant increase at 90, 135 and 180 days after plant growth. The maximum increase in plant spread both in North-South (2.27, 2.53 and 2.60 m respectively) and East-West (2.08, 2.28 and 2.38 m respectively) directions were noticed in T_{12} while, lowest increment in plant spread were recorded in T_9 (1.91, 2.07 and 2.21 m) (N-S) and (1.73, 1.86 and 1.97 m) (E-W) respectively.

The increased plant spread in a plants treated with T_{12} might be due to the integrated application of balanced dose of fertilizers and foliar application of bio-stimulants and micronutrients had led to release the major nutrients and made it available to the plants at the critical physiological growth stages of pomegranate, which resulted in proper root growth, that might have enhanced the nutrient uptake and reflected in increasing the plant spread. The findings are in line with Marathe *et al.* (2017) [13], Gajbhiye *et al.* (2020) [5], Kumar *et al.* (2020) [9] and Mishra and Polara (2020) [15] in pomegranate.

3.4 Number of shoots

The T_{12} resulted in obtaining the maximum number of shoots (33.96 and 35.75) which was statistically similar with T_{11} (31.03 and 33.77), while the lesser number of shoots were reported in T_9 (20.87 and 22.19). The data of pooled analysis of two years study indicated that, the highest number of shoots were noticed in T_{12} (34.85) which was at par with T_{11} (32.40) and lowest value was observed in T_9 (21.53) (Table 5).The increase in number of shoots in T_{12} might be attributed due to the application of optimal dose of nutrients at plant requirement stage using different organic, inorganic and bio-stimulant sources through soil as well as foliar application has led to increase in the nutrient availability and also enhanced the activity of plant growth promoting substance that facilitates the accumulation of more photosynthates in plants leading to the more production of shoots compared to other treatments. These results are also in confirmation with Hiremath *et al.* (2018) [6] in pomegranate.

Table 2: Effect of integrated nutrient management on stem parameters of pomegranate plants

Treatments	Stem girth (mm)						Extent increase in stem girth growth (mm)			Number of stems per plant
	Vegetative stage (20 days after bahar treatment)			Harvesting stage						
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-2021
T_1	42.37	46.69	44.53	46.07	50.89	48.48	3.70	4.20	3.95	5.93
T_2	45.10	50.65	47.88	50.10	56.25	53.18	5.00	5.60	5.30	4.99
T_3	38.94	45.11	42.03	44.54	51.11	47.83	5.60	6.00	5.80	4.02
T_4	44.31	49.87	47.09	49.41	55.77	52.59	5.10	5.90	5.50	5.75
T_5	38.14	43.25	40.70	42.74	48.55	45.65	4.60	5.30	4.95	5.04
T_6	40.63	46.27	43.45	45.73	52.17	48.95	5.10	5.90	5.50	5.88

T7	39.50	46.14	42.82	45.50	52.74	49.12	6.00	6.60	6.30	4.03
T8	42.63	49.73	46.18	49.03	56.73	52.88	6.40	7.00	6.70	4.05
T9	41.57	45.94	43.76	45.57	50.74	48.16	4.00	4.80	4.40	4.97
T10	40.60	46.43	43.52	45.00	51.53	48.27	4.40	5.10	4.75	5.82
T11	41.53	48.58	45.05	47.93	55.78	51.86	6.40	7.20	6.80	4.10
T12	40.79	48.09	44.44	47.49	55.49	51.49	6.70	7.40	7.05	5.82
S.Em ±	1.09	1.15	1.14	0.98	1.12	1.03	0.15	0.13	0.12	-
C. D @5%	3.10	3.23	3.20	2.88	3.28	3.02	0.42	0.38	0.34	-

Table 3: Effect of integrated nutrient management on plant spread (North-South) (m) of pomegranate

Treatments	Plant spread (N-S) (m)											
	Vegetative and flowering stage						Fruiting stage					
	45 days			90 days			135 days			180 days		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T1	1.78	1.85	1.82	1.92	2.04	1.98	2.13	2.18	2.16	2.25	2.33	2.29
T2	1.80	1.88	1.84	1.96	2.14	2.05	2.15	2.23	2.19	2.33	2.44	2.39
T3	1.75	1.83	1.83	1.89	2.09	2.04	2.14	2.26	2.24	2.30	2.43	2.38
T4	1.76	1.86	1.81	1.86	2.03	1.95	2.09	2.14	2.12	2.24	2.38	2.31
T5	1.78	1.87	1.79	1.93	2.14	1.99	2.17	2.30	2.20	2.34	2.41	2.37
T6	1.82	1.83	1.83	1.98	2.16	2.07	2.20	2.35	2.28	2.35	2.46	2.41
T7	1.82	1.89	1.86	2.01	2.18	2.10	2.24	2.38	2.31	2.35	2.50	2.43
T8	1.86	1.90	1.88	2.09	2.24	2.17	2.30	2.47	2.39	2.42	2.56	2.49
T9	1.73	1.85	1.79	1.86	1.96	1.91	2.05	2.09	2.07	2.15	2.26	2.21
T10	1.75	1.90	1.83	1.90	2.01	1.96	2.10	2.16	2.13	2.20	2.39	2.30
T11	1.89	1.92	1.91	2.15	2.26	2.21	2.34	2.50	2.42	2.46	2.62	2.54
T12	1.90	1.94	1.92	2.18	2.35	2.27	2.46	2.59	2.53	2.52	2.68	2.60
S.Em ±	NS	NS	NS	0.05	0.05	0.05	0.07	0.07	0.07	0.06	0.06	0.05
C. D @5%	NS	NS	NS	0.15	0.15	0.15	0.21	0.20	0.21	0.16	0.17	0.16

Table 4: Effect of integrated nutrient management on plant spread (East-West) (m) of pomegranate plants at monthly intervals

Treatments	Plant spread (E-W) (m)											
	Vegetative and flowering stage						Fruiting stage					
	45 days			90 days			135 days			180 days		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T1	1.56	1.71	1.64	1.73	1.86	1.80	1.85	1.98	1.92	1.93	2.19	2.06
T2	1.65	1.78	1.72	1.84	1.92	1.88	1.89	2.10	2.00	2.05	2.23	2.14
T3	1.69	1.70	1.70	1.78	1.93	1.86	1.95	2.13	2.04	2.06	2.24	2.15
T4	1.63	1.74	1.69	1.79	1.82	1.81	1.90	2.09	2.00	1.96	2.18	2.07
T5	1.65	1.76	1.71	1.80	1.90	1.85	1.90	2.14	2.02	2.05	2.22	2.14
T6	1.71	1.81	1.76	1.85	1.96	1.91	1.98	2.18	2.08	2.10	2.26	2.18
T7	1.71	1.80	1.76	1.88	2.01	1.94	2.04	2.20	2.12	2.11	2.28	2.19
T8	1.75	1.86	1.81	1.91	2.05	1.98	2.10	2.28	2.19	2.20	2.41	2.31
T9	1.62	1.75	1.69	1.64	1.81	1.73	1.78	1.94	1.86	1.86	2.07	1.97
T10	1.65	1.79	1.72	1.71	1.88	1.80	1.85	2.01	1.93	1.97	2.18	2.08
T11	1.76	1.88	1.82	1.99	2.09	2.04	2.19	2.31	2.25	2.24	2.37	2.31
T12	1.79	1.89	1.84	2.01	2.14	2.08	2.20	2.35	2.28	2.30	2.46	2.38
S.Em ±	NS	NS	NS	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.06
C. D @5%	NS	NS	NS	0.12	0.12	0.12	0.15	0.14	0.15	0.18	0.17	0.18

3.5 Shoot girth (mm)

A significant increase in shoot girth during first and second year of the study was recorded in T_{12} (8.74 and 8.95 mm) in which T_{11} (8.10 and 8.46 mm) showed statistical similarity with the best treatment. While the minimum shoot girth was noticed in T_9 (6.20 and 6.02 mm). The compiled data of two years study revealed that, the maximum shoot girth was recorded in T_{12} (8.84 mm) which was at par with T_{11} (8.28 mm) and minimum response towards enhancing shoot girth size was observed in T_9 (6.11 mm) (Table 5).

The probable increment in shoot girth might be due to balanced dose of application of nutrients through organic and inorganic sources through soil and foliar application method have led to increase in the soil microbes populations which might have helped in release of growth factors such as auxins, gibberellins and cytokinins which directly helps in cell elongation and cell division hence resulted in the increment of shoot girth. The results are supported with observations of Aziz *et al.* (2017) [4], Kurer *et al.* (2017) [11], Maji *et al.* (2017) [14], Hiremath *et al.* (2018) [6], Kumar *et al.* (2020) [9], Mishra and Polara (2020) [15] and Virginio (2020) [19] in pomegranate.

3.6 Shoot length (cm)

The INM treatments significantly enhanced the length of reproductive shoots at 30, 60 and 90 days after plant growth (28.15 to 46.85 cm) which is presented in Table 6. The observation was recorded at 30, 60 and 90 days after plant growth, the pooled data suggested that, the maximum shoot length extension was observed in T_{12} (29.25, 39.41 and 46.85 cm) which was found statistically similar with T_{11} (27.60, 37.47 and 44.62 cm) respectively and lesser extension in shoot length was reported in T_9 (18.00, 23.02 and 28.15 cm).

A significant increase in shoot length might be due to integrated application of organics, inorganic and foliar application of bio-stimulants as well as micronutrients resulted in the quick absorption of the supplied food material by the roots and transmission of the same to the main trunk resulted in increasing the shoot length growth. Shaban and Haseeb (2009) [17] in guava reported that, due to alteration in various enzymatic activities within the plants such as peroxidase and catalase etc., which promotes shoot growth through carbohydrate metabolism process.

Table 5: Effect of integrated nutrient management on number of shoots and shoot girth (mm) of pomegranate plants

Treatments	Number of shoots			New shoot girth (mm)		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1	24.02	25.75	24.88	6.89	6.80	6.85
T_2	28.57	28.37	28.47	6.97	7.23	7.10
T_3	29.36	30.20	29.78	7.35	7.86	7.61
T_4	26.32	26.32	26.32	6.46	7.21	6.84
T_5	26.22	25.95	26.08	6.94	7.10	7.02
T_6	27.45	28.47	27.96	7.44	7.66	7.55
T_7	29.19	30.87	30.03	7.51	8.01	7.76
T_8	30.50	32.18	31.34	7.90	8.05	7.97
T_9	20.87	22.19	21.53	6.20	6.02	6.11
T_{10}	23.40	24.80	24.10	6.36	6.80	6.58
T_{11}	31.03	33.77	32.40	8.10	8.46	8.28
T_{12}	33.96	35.75	34.85	8.74	8.95	8.84
S.Em ±	1.06	1.19	1.10	0.23	0.29	0.24
C. D @5%	3.12	3.50	3.22	0.67	0.84	0.69

Table 6: Effect of integrated nutrient management on shoot length (cm) of pomegranate plants

Treatments	New shoot length (cm)								
	30 days			60 days			90 days		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1	20.32	22.55	21.44	27.35	28.51	27.93	32.90	34.27	33.59
T_2	21.90	22.81	22.36	31.47	32.58	32.03	36.82	36.67	36.75
T_3	22.51	23.42	22.97	31.94	33.37	32.66	38.37	37.98	38.18
T_4	20.57	21.08	20.83	28.12	29.80	28.96	33.38	35.06	34.22
T_5	20.30	21.18	20.74	26.05	29.48	27.77	32.24	33.28	32.76
T_6	21.17	22.79	21.98	30.62	31.91	31.27	36.51	36.24	36.38
T_7	23.93	24.22	24.08	32.79	33.69	33.24	40.76	39.58	40.17
T_8	25.60	27.30	26.45	35.13	36.20	35.67	41.87	42.75	42.31
T_9	17.62	18.37	18.00	22.26	23.77	23.02	27.25	29.04	28.15
T_{10}	19.15	21.13	20.14	25.22	27.35	26.29	29.06	31.15	30.11
T_{11}	26.52	28.67	27.60	37.59	37.35	37.47	44.51	44.72	44.62
T_{12}	28.57	29.93	29.25	38.98	39.83	39.41	46.61	47.09	46.85
S.Em ±	0.79	0.77	0.65	1.05	1.13	1.00	1.45	1.30	1.41
C. D @5%	2.30	2.24	1.90	3.07	3.30	2.88	4.28	3.91	4.15

3.7 Number of leaves per shoot

The number of leaves produced per new shoot at 30, 60 and 90 days after plant growth were found significant among the different INM treatments and which is furnished in Table 7. The maximum number of leaves were recorded in T_{12} (43.80, 59.25 and 68.37) at 30, 60 and 90 days after plant growth respectively whereas, minimum number of leaves per shoot were noticed in T_9 (25.44, 33.21 and 40.90).

The production of higher number of leaves in T_{12} might be due to the application of optimum RDF along with organic manures and bio-fertilizers has led to increase in the nutrient absorption capacity and also the foliar application of bio-stimulants and micronutrients stimulated physiological signals which served as a plant growth promoters that induced higher rate of cell division and cell elongation in sub apical meristem of pomegranate shoots hence, resulted in production of more number of leaves per shoot. This findings was in line with Aziz *et al.* (2017) [4], Kurer *et al.* (2017) [11], Maji *et al.* (2017) [14] and Virginio (2020) [19] in pomegranate.

3.8 Leaf area (cm^2)

During vegetative stage T_{12} (8.56 and 8.81 cm^2) recorded the maximum leaf area and T_{11} (8.07 and 8.23 cm^2) found to be statistically similar with the superior treatment. The minimum leaf area was observed in T_9 (5.73 and 5.98 cm^2). The pooled data of two years study suggested similar pattern with the highest leaf area was noticed in T_{12} (8.69 cm^2) which was statistically at par with T_{11} (8.15 cm^2) while the lesser leaf area was reported in T_9 (5.86 cm^2). At the time of fruiting stage, the highest leaf area was observed in T_{12} (11.38 and 11.45 cm^2) which was on par with T_{11} (10.44 and 10.49 cm^2). The minimum leaf area was observed in T_9 (8.28 and 8.35 cm^2). The pooled data of two years experiment revealed that, the maximum leaf area was noticed in T_{12} (11.42 cm^2) which was statistically at par with T_{11} (10.47 cm^2) while the minimum leaf area was reported in T_9 (8.32 cm^2) (Table 8).

The increase in leaf area may be due to the combined application of required quantity of nutrients in the form of inorganic (RDF and micronutrients), bio-fertilizers and bio-stimulants through soil and foliar application has resulted in the higher uptake and accumulation of nutrients in the leaf tissues which in turn ensured better photosynthetic efficiency, causing greater synthesis, translocation and accumulation of carbohydrates within the leaf. The other probable reason may be due to better plant spread in T_{12} which might have resulted in maximum light interception into the canopy thereby resulting in broader leaves and higher leaf area as compared to other treatments. Similar findings were also reported by Aziz *et al.* (2017) [4], Kumar *et al.* (2020) and Hussein *et al.* (2021) [8] in pomegranate.

Table 7: Effect of integrated nutrient management on production of leaves per shoot (No.) of pomegranate plants at monthly intervals

Treatments	Number of leaves per new shoot								
	30 days			60 days			90 days		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1	32.77	31.27	32.02	39.37	43.34	41.36	48.44	49.45	48.95
T_2	35.11	33.67	34.39	46.62	47.08	46.85	56.67	54.05	55.36
T_3	37.51	34.98	36.25	47.95	48.59	48.27	57.88	55.56	56.72
T_4	30.29	32.06	31.18	40.23	41.18	40.71	49.94	49.77	49.86
T_5	30.18	30.28	30.23	41.13	43.36	42.25	52.76	52.35	52.56
T_6	36.67	33.24	34.96	44.78	45.93	45.36	56.41	53.88	55.15
T_7	37.51	36.58	37.05	48.94	50.68	49.81	59.73	56.69	58.21
T_8	39.28	39.75	39.52	51.55	53.74	52.65	60.35	60.08	60.22
T_9	24.84	26.04	25.44	31.93	34.48	33.21	41.12	40.68	40.90
T_{10}	30.60	28.15	29.38	37.54	39.01	38.28	45.28	43.05	44.17
T_{11}	41.46	41.72	41.59	52.44	54.54	53.49	64.61	63.14	63.88
T_{12}	43.51	44.09	43.80	57.95	60.54	59.25	67.83	68.90	68.37
S.Em ±	1.23	1.37	1.40	2.02	2.13	2.03	2.34	2.77	2.51
C. D @5%	3.57	3.97	4.10	5.92	6.25	6.01	6.90	8.22	7.40

Table 8: Effect of integrated nutrient management on leaf area (cm^2) of pomegranate plants observed at different growth stages

Treatments	Leaf area (cm^2)					
	Vegetative stage			Fruiting stage		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1	6.37	6.73	6.55	9.50	9.42	9.46
T_2	6.68	7.04	6.86	9.84	9.92	9.88
T_3	7.28	7.39	7.34	10.16	10.13	10.15
T_4	6.78	6.91	6.85	9.85	9.92	9.89
T_5	6.66	6.92	6.79	9.92	10.03	9.98
T_6	7.13	7.18	7.16	10.11	10.18	10.15
T_7	7.79	7.86	7.83	10.19	10.16	10.18
T_8	7.88	7.96	7.92	10.26	10.31	10.29
T_9	5.73	5.98	5.86	8.28	8.35	8.32
T_{10}	6.33	6.37	6.35	8.71	8.76	8.74
T_{11}	8.07	8.23	8.15	10.44	10.49	10.47
T_{12}	8.56	8.81	8.69	11.38	11.45	11.42
S.Em ±	0.20	0.22	0.22	0.38	0.35	0.36
C. D @5%	0.56	0.64	0.63	1.11	1.02	1.06

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