Scientia Horticulturae 214 (2017) 114–121

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Response of nutrient supplementation through organics on growth, yield and quality of pomegranate

R.A. Marathe[a,*], Jyotsana Sharma[a], A.A. Murkute[b], K. Dhinesh Babu[a]

[a] ICAR – National Research Centre on Pomegranate, Solapur 413255, Maharashtra, India
[b] ICAR – Central Citrus Research Institute, Nagpur – 440033, Maharashtra, India

ARTICLE INFO

Article history:
Received 2 July 2016
Received in revised form 17 October 2016
Accepted 20 November 2016
Available online 26 November 2016

Keywords:
Diseases
Green manures
Growth
Microbial count
Nutrition
Organic
Pomegranate
Quality
Yield

ABSTRACT

The study was carried out on pomegranate (*Punica granatum* L.) cv. 'Bhagwa' to investigate efficacy of organics on plant nutrient uptake, growth behaviour, fruit yield and quality attributes, disease incidence and soil health. Organic nutrient sources, namely, farm yard manure (FYM), vermicompost (VC), poultry manure (PM), and *insitu* green manuring (GM) through sun hemp (*Crotalaria juncea* L.), *exsitu* GM through Glyricidia (*Gliricidia sepium*), Karanj (*Pongamia pinnata*) and neem (*Azadirachta indica*), and recommended dose of inorganic fertilizers against control were evaluated. The results revealed significant decrease in soil pH and electrical conductivity and substantial increase in soil organic carbon content in all organic manuring treatments over control. Application of FYM had the highest availability of most of the nutrients (P: 64.4 and K: 578.7 kg ha^{-1}; Cu: 15.1, Zn: 2.30 and Mn: 8.4 ppm) in the soil. Three years pooled data showed that the highest P (0.182%), K (1.06%) and Fe (176.7 ppm) contents in the leaves were supplied by PM, while N (2.33%) was by FYM. Although, during first year, vegetative growth of the plants was better in inorganic fertilizers than other treatments, second year onwards it was increased significantly in FYM, VC and GM with sun hemp treatments. Maximum fruit yield was obtained with the application of PM (3.96 kg tree^{-1}) followed by FYM (3.86 kg tree^{-1}). All of the organic manuring treatments resulted in improved fruit quality characteristics *viz.* fruit juice content, juice acidity, TSS and TSS: acid ratio as compared to inorganic fertilizers. Organic manuring with neem recorded the lowest disease index (5.84) on plants. Similarly, increased microbial load in the rhizosphere soil in terms of *P. fluorescence* (20.3×10^{-4} cfu g^{-1}) and *Azotobacter chroococcum* (17.4×10^{-3} cfu g^{-1}) population was recorded in FYM. *A. niger* (13.6×10^{-4} cfu g^{-1}) and PSM (15.6×10^{-5} cfu g^{-1}) activity was higher in GM with Karanj and Sun hemp, respectively.

1. Introduction

Pomegranate (*Punica granatum* L.) is an important fruit crop of arid and semi-arid regions of the world. It has a very high export potential owing to its antioxidant and nutraceutical values (Newman and Lansky, 2007). Consumer demand for fresh and processed products like juice, wine, syrup and *anardana* an acidulant is also escalating day by day (Saxena et al., 1984). With increasing health consciousness, the demand for organically produced pomegranate fruits is growing in Middle East, America and European countries. Although native to hot dry regions of Iran, Afghanistan and adjoining areas (De Candolle, 1967) pomegranate has been widely cultivated in Mediterranean regions of Asia, Africa and Europe. India is one of the leading producers of pomegranate in world having area over 1.13 lakh ha with annual production 7.44 lakh tonnes. In India, predominantly, pomegranate is cultivated in vast areas of marginal lands having very low organic carbon content (Marathe et al., 2015) and microbial population where yields were limited due to deficiency of more than 2–3 nutrients (Raghupati and Bhargava, 1998).

Under these circumstances, during last few decades attempts are being made to improve production by adopting practice of high external input agriculture (HEIA). In due course of time, indiscriminate use of, fertilizers, pesticides and other chemicals has resulted in irrecoverable deterioration of soil physical, chemical and microbiological heath coupled with unsustainable productivity

* Corresponding author. Present address: ICAR – Central Citrus Research Institute, Nagpur - 440033, Maharashtra, India.
E-mail addresses: ramarathe28@gmail.com (R.A. Marathe), jyotisharma128@yahoo.com (J. Sharma), ashutoshmurkute@gmail.com (A.A. Murkute), ckdhinesh@gmail.com (K.D. Babu).

http://dx.doi.org/10.1016/j.scienta.2016.11.024
0304-4238/

in many traditional pomegranate belts. The problem seems to be compounded further where organic manures find no place in fertilizer application programme. These problems warrant a revision of ongoing agricultural practices and adoption of some new alternative strategies. In view of this, concepts like organic pomegranate cultivation, claimed to be the benign alternative for sustainable production, would play a vital role. The role of soil organic matter is well established in improving physic-chemical properties (Marathe et al., 2009) and governing the nutrient fluxes (Marathe et al., 2012) in sweet orange as well as increasing microbial biomass (Marathe et al., 2010, 2011; Mir et al., 2015) in pomegranate.

Considering the medicinal importance of pomegranate fruits and plant parts as a whole, more rational approach to organic cultivation including exploitation of various locally available organics such as farm yard manure, vermicompost, poultry manure and green manuring should be practically implemented to rejuvenate the depleted soil fertility and enrich the available pool of nutrients to the plants, which could benefit the crop having long maturity time. In this background information, the present study, therefore, was focussed and planned with the objective to evaluate the efficacy of various sources of organic and green manures on cropping behaviour, soil properties, nutrient uptake and quality attributes of pomegranate under hot semi-arid tropical climate of central India.

2. Materials and methods

2.1. Experimental site

The field experiment was conducted during 2007–2013 at the research farm of ICAR – National Research Centre on Pomegranate, Solapur, Maharashtra, India located at 17°6′ N latitude, 75°90′ E longitude, at an altitude of 487 m above mean sea level. The climate of the study area is semi-arid, with hot summer, moderate winter and mean annual maximum and minimum temperature of 40.4 °C and 14.9 °C, respectively. The average annual rainfall of 694 mm occurs mostly during the months of July–September.

2.2. Experimental setup

The original experimental site was barren land, full of gravels and weathered murrum having montmorillonitic mineralogy. As per land capability classification it was classified under Group V land having soil depth and coarse fragment limitations. Taxonomically the soil is classified as Entisol (Lithic Ustorthents). The physico-chemical properties of the soil were: pH 7.66, electrical conductivity 0.18 $dS\,m^{-1}$, organic carbon 0.38% and calcium carbonate 6.24%. The available N, P and K content of surface soil were 190.0, 11.5 and 238.4 $kg\,ha^{-1}$, respectively. Trapezoidal pits of 1.50 × 1.50 m top and 1.20 × 1.20 m bottom width having 0.6 m depths were dug in the field at plantation spacing of 4.5 × 4 m. The pits were refilled with pond soil and used for plantation.

2.3. Experimental design

The experiment was laid out in a randomized block design comprising of 9 treatments with 3 replications having 3 plants per replication. Various treatments were – nutrient application through various organic sources *viz*., farm yard manure (FYM) (T_1), vermicompost (VC) (T_2), poultry manure (PM) (T_3), *insitu* green manuring (GM) with sun hemp (*Crotalaria juncea* L.) (T_4), *exsitu* green manuring with Glyricidia (*Gliricidia sepium*) (T_5), *exsitu* green manuring with Karanj (*Pongamia pinnata*) (T_6), *exsitu* green manuring with neem, *(Azadirachta indica)* (T_7), recommended dose of nutrients supplied through inorganic fertilizers (T_8) and control (T_9) i.e. without any fertilization. Organic manures were computed on N-equivalent basis. The nutritional status of various organics used in the present study is mentioned in Table 1. Green manure crop sun hemp was grown near the plant for the period of 60 days during rainy season in tree basin (4.5 × 4 sq. m area) and was incorporated at the time of flowering during the last week of August. Chopped lopping of other green manure crops was buried in plant basin and covered with soil. Recommended dose of fertilizers was 250 g N + 125 g P + 125 g K during second year and 500 g N + 125 g P + 250 g K to bearing trees during third year. Sources of inorganic fertilizers used were urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O). Urea was applied in three split doses. Full dose of P_2O_5, K_2O and one third N was applied with the onset of monsoon in June month. The remaining quantity of N was applied in two equal split doses at 2 months interval.

2.4. Crop husbandry

Farm yard manure at the rate of 20 kg per pit was applied in each pit and thoroughly mixed with soil material before plantation of the seedlings. In all the treatments, 150-days-old air-layered saplings of pomegranate cv. ‘Bhagwa’ were planted during October 2007 and maintained by adopting similar cultivation practices. Organic manuring treatments were imposed on two year old plants from 2009. Due to severe infestation of bacterial blight disease, as a management practice, plants were cut to ground level during October 2010. All plant debris were disinfected by spraying bleaching powder on the surface and irradicated. Again plants were allowed to grow and treatments were imposed. Standard package of practices was followed for growing plants.

2.5. Soil analysis

Composit soil samples at 30 cm depth (45 cm away from the drip line of the tree) and weighing up to 1 kg, were collected before fruiting season (year 2012) and analysed for various chemical properties and fertility status. Soil pH and electrical conductivity (EC) were measured in a 1:2.5 (w/v) aqueous solution while calcium carbonate was determined following standard procedure (Jackson, 1973). Soil organic carbon was determined according to wet oxidation method (Walkley and Black, 1934). Available N was determined by alkaline permanganate method (Subbiah and Asija, 1956). Available P was estimated by Olsen's extractant (0.05 N $NaHCO_3$, pH 8.50) method (Watanabe and Olsen, 1965). Available K was determined by extracting the soil with neutral normal ammonium acetate method (Morwin and Peach, 1951). The DTPA-extractable micronutrients, *viz.* Fe, Mn, Zn and Cu were determined by the method of Lindsay and Norvell (1978) using Atomic Absorption Spectrophotometer (Perkin Elmer, USA make Analyst 400).

2.6. Leaf nutrient content

A representative leaf sample of 50 fully matured and expanded current season leaves located at the 8th to 10th position from apex were collected (Bhargava and Dhandar, 1987; Marathe and Dhinesh Babu, 2015) during every year. The collected leaf samples were washed thoroughly in sequence with water, liquid soap, acidic water and glass redistilled water and dried in shade for four days followed by oven drying at 70 °C till it achieved constant weight. The dried samples were ground, mixed well and used for analysing total N by micro-kjeldhal steam distillation method. The samples were further digested in di-acid (nitric acid – perchloric acid in 9:4 v/v ratio) mixture and used for analysing P using Vanadomolybdo phosphoric acid method, K using flame photometer, Ca and Mg by titrimetric method employing disodium salt of EDTA (Chapman and Pratt, 1961). Micronutrients *viz*. Fe, Zn, Mn

Table 1
Composition of different organic manues added in soil (oven dry basis).

Organic manures	N	P	K	Ca	Mg	Mn	Zn	Cu	Fe
	(%)					(mg kg^{-1})			
FYM	0.65	0.48	0.76	0.21	1.00	590	87	85	1260
VC	1.62	0.32	0.84	0.22	0.87	630	94	61	800
PM	2.55	1.64	1.26	0.36	0.41	564	77.3	74.2	689
GM Sunhemp	2.32	0.34	1.54	1.26	0.54	140	28	14	455
GM Glyricidia	1.12	0.30	1.06	0.95	0.40	120	35	22	268
GM Karanj	0.72	0.12	1.62	1.58	0.45	98	45	28	224
GM Neem	1.23	0.14	1.86	1.88	0.52	87	40	20	203

FYM – farm yard manure, VC – vermicompost, PM – poultry manure, GM – green manuring.

and Cu were analysed using Atomic Absorption Spectrophotometer (Perkin Elmer, USA make Analyst 400).

2.7. Plant growth, physico-chemical analysis

Vegetative growth in terms of plant height and plant spread was recorded in each year. The fruit yield data were recorded both in terms of number (count) and fruit weight basis during the year 2013.

The harvested fruits were utilized for analysing physico-biochemical properties. Total soluble solids (TSS), acidity, juice content were estimated using standard procedures (AOAC, 1990).

2.8. Physiological parameters and diseases

Chlorophyll content in the leaf was measured using chlorophyll meter (KONICA MINOLTA SPAD-502) as indicated by SPAD values.

Incidence of bacterial blight disease (BBD) on leaves and on lemon size fruits of the plants were recorded during 2012. Cumulative effect of disease incidence on all plant parts was calculated using following formula.

BBD Index = 0.10 L + 0.70 F + 0.20 S; where I-incidence on leaves, I-incidence on fruits and I-incidence on stems.

Infected fruits were removed from the plant to check further spread of disease before adopting chemical treatment.

2.9. Microbial population in soil

At the end of the experiment, pure and viable soil microbes were isolated using serial dilution technique. Count of various microorganisms viz. *Aspergillus niger, Pseudomonas fluorescence,* Potash solubilizing organisms and *Azotobacter* were measured using Rose Bengal Agar Base, King's B, Aleksandrov agar and Azotobacter Agar (Mannitol) mediums, respectively (Whitman, 2010).

2.10. Statistical analysis

The experiment was conducted in randomized block design with each treatment replicated thrice. To detect significant difference among different treatments, statistical analysis for shortest significant range tests was performed using Tukey's HSD test by using SAS (2011) software.

3. Results and discussion

3.1. Soil chemical properties and fertility status

Applications of different organics were effective in decreasing pH and EC values of the soil. Maximum decrease in pH (6.27) and EC (0.38 dS m^{-1}) was observed in GM with sun hemp treatment compared to control (Table 2). The decrease in soil pH with organic sources was attributed to the production of organic acids namely oxalo-acetic acid, glutamic acid while the lowering of EC values were ascribed to the increased permeability and consequent leaching of the salts (Srikanth et al., 2000). Results on similar line have been reported by Marathe et al. (2009) in sweet orange orchards.

The organic carbon content was significantly higher in all the organic manuring treatments (0.56–1.18%) than inorganic fertilizer (0.46%) and control (0.42%) (Table 2). The highest organic carbon was noted with the incorporation of FYM followed by GM with sun hemp and PM. Addition of substantial quantity of organic matter, thereby better shoot growth along with concomitant higher root biomass generation and decomposition of biomass in the soil could have increased organic carbon content (Bellakki et al., 1998). Furthermore, the manures themselves contributed partially in increasing the organic carbon of the soil (Bhriguvanshi, 1988). Increased organic carbon content with the incorporation of FYM was corroborated to studies in guava (Trivedi et al., 2012). It may be noted that the build up of organic carbon was not in the proportion of quantity of organic manure applied, which might have been due to variation in the amount applied, nutrient composition, decomposition and release pattern of different organics in the soil.

All manurial treatments significantly improved the available macro- and micro-nutrient contents in the soil (Table 2). GM with sun hemp increased maximum N (359.6 kg ha^{-1}) than inorganic fertilizer (297.2 kg ha^{-1}) and control (259.2 kg ha^{-1}). Incorporation of FYM, PM and VM were equally effective in increasing N content in soil, that could be due to the release of N through the decomposition of organic manures (Narwal and Antil, 2005). Maximum P (64.4 kg ha^{-1}) was recorded in FYM followed by PM (56.4 kg ha^{-1}) application, which was significantly higher over other organic manures (24.7–28.7 kg ha^{-1}), inorganic fertilizers (29.1 kg ha^{-1}) and control (20.1 kg ha^{-1}). PM and FYM contain 1.64 and 0.48% P, respectively, which become available during the process of decomposition. The acidulation effect of FYM on applied and native P enhanced the P availability (Prakash et al., 2002). Maximum K was observed in FYM (578.7 kg ha^{-1}) followed by PM treatment. Almost all organic manures and inorganic fertilizer treatments recorded higher availability of K in soil. Black clay soils formed on Deccan plateau of central India are rich in potash bearing minerals which might have resulted in higher availability of K (Malewar and Patil, 1997). Plots where organic material was applied had several folds increase in micronutrient content over initial contents. Incorporation of FYM recorded the highest content of Cu (15.1 mg kg^{-1}), Zn (2.30 mg kg^{-1}) and Mn (8.4 mg kg^{-1}) in the soil. Such an increase in these micronutrients was attributed to the mineralization of organically bound forms and formation of stable water soluble complexes or organic chelates of higher stability, which decreases their susceptibility to absorption, fixation and/or precipitation (Bellakki et al., 1998; Swarup, 1984). These findings are corroborated with results in apricot (Sharma et al., 2011) and litchi (Anubha Rani et al., 2013).

Table 2
Effect of organic nutrient sources on soil chemical properties and fertility status.

Treatments	pH	EC ($dS\,m^{-1}$)	Organic Carbon (%)	$CaCO_3$ (%)	Available macronutrients ($kg\,ha^{-1}$)			Available micronutrients ($mg\,kg^{-1}$)			
					N	P	K	Cu	Zn	Fe	Mn
FYM	7.65^{A}	0.46^{ABC}	1.18^{A}	6.78	346.0^{AB}	64.5^{A}	578.7^{A}	15.1^{A}	2.30^{A}	15.6^{CD}	8.4^{A}
VC	7.62^{A}	0.55^{AB}	0.58^{BCD}	7.17	297.2^{BC}	28.4^{B}	280.0^{E}	12.9^{AB}	0.79^{C}	14.6^{D}	6.6^{ABC}
PM	6.69^{B}	0.48^{ABC}	0.68^{BC}	8.44	345.9^{AB}	56.4^{A}	451.7^{BC}	9.3^{CDE}	1.39^{B}	16.3^{CD}	5.2^{C}
GM Sun hemp	6.27^{C}	0.40^{BC}	0.76^{B}	7.29	359.6^{A}	26.5^{B}	406.9^{CD}	9.2^{DE}	0.74^{C}	15.9^{CD}	5.4^{C}
GM Glyricidia	7.44^{A}	0.51^{ABC}	0.68^{BC}	8.14	298.1^{BC}	28.7^{B}	399.5^{CDE}	12.9^{ABC}	0.84^{C}	16.9^{CD}	6.3^{BC}
GM Karanj	7.60^{A}	0.56^{AB}	0.65^{BC}	8.02	327.4^{AB}	25.1^{B}	308.0^{DE}	12.2^{ABCD}	0.73^{C}	17.8^{ABC}	5.3^{C}
GM Neem	7.66^{A}	0.38^{C}	0.57^{CD}	7.38	313.4^{ABC}	24.7^{B}	362.1^{CDE}	10.5^{BCDE}	0.61^{C}	19.8^{AB}	7.9^{AB}
Inorganic fertilizers	7.62^{A}	0.60^{A}	0.46^{D}	7.38	334.07^{AB}	29.1^{B}	555.13^{AB}	14.3^{A}	0.94^{BC}	20.28^{A}	6.55^{ABC}
Control	7.74^{A}	0.61^{A}	0.42^{D}	8.66	259.20^{C}	20.1^{B}	298.67^{DE}	7.1^{E}	0.63^{C}	17.30^{BCD}	5.22^{C}
General Mean	7.36	0.51	0.66	7.69	320.09	33.7	404.53	11.5	1.00	17.16	6.31
CV(%)	1.75	11.0	9.69	9.7	6.34	15.0	10.5	10.6	16.2	5.8	11.1
SE(d)	0.11	0.05	0.05	0.61	16.6	4.13	34.5	0.99	0.13	0.82	0.57
Tukey's HSD at 5%	0.37	0.16	0.19	NS	58.9	14.7	122.8	3.54	0.47	2.89	2.03

FYM – farm yard manure, VC – vermicompost, PM – poultry manure, GM – green manuring.
Means sharing a common letter within the column are not significant by Tukey's HSD test at $P < 0.05$.

3.2. Leaf nutrient contents

The integrated effect of soil nutrient availability coupled with improved physical conditions of soil was reflected in increased uptake of macro and micro-nutrients under different organic manuring treatments (Table 3). Pooled data showed that leaf N content significantly varied from 1.64 to 2.33% and was maximum with the application of FYM. Similarly maximum leaf P (0.182%) and K (1.06%) contents were observed in PM treatment Application of VC and GM with sun hemp was on par with PM in increasing macro-nutrient uptake by the plants. The greater multiplication of microbes in organic manures converted organically bound N to organic form and increased uptake of N (Chauhan, 2008). Addition of organic residues induced production of oxalic acid by the plants that resulted in mobilization of immobile soil P and helped in increasing the uptake of P by the plants (Dotaniya et al., 2014; McDowell et al., 2000). Increased macro-nutrient uptake with the addition of organics was reported in several fruit crops *viz.* guava (Trivedi et al., 2012), sweet orange (Marathe et al., 2012) and Litchi (Anubha Rani et al., 2013).

Micronutrient contents of the leaf was also influenced significantly by different organic treatments in similar trend. Leaf Fe and Zn contents significantly varied from 146.5 to 176.7 and 43.7 to 50.2 $mg\,kg^{-1}$, respectively amongst the treatments (Table 3). Maximum leaf content of Fe was observed with the application of PM while Zn was in GM with sun hemp. GM with gliricidia, sun hemp and karanj were equally effective in increasing leaf micronutrient contents. The increased biological activity in the soil was due to addition of organic manures, which solubilise the fixed nutrients, make them available to the plants and increase its uptake (Chonkkar, 1994). Marathe et al. (2009) reported increased availability and uptake of Fe, Zn, Mn and Cu in sweet orange with organic manures either alone or in combination with inorganic fertilizers or green manure or biofertilizers. Seshadri and Madhavi, (2001) and Malewar and Patil (1999) have also reported similar findings.

3.3. Plant growth and leaf chlorophyll content

Organic amendments also exerted a significant effect on vegetative growth of the plants during the year 2010 and 2012. During initial years (2009 and 2010) of plant growth, the highest plant height (178.9 and 274.9 cm) and plant spread (160.5 and 238.4 cm) was observed in the application of inorganic fertilizers (Table 4). But afterwards, organic manure treatments performed better than inorganic fertilizer treatment and recorded highest plant height (128.7 cm) with the application of VM followed by GM with Sun hemp (125.8 cm). During the year 2012, the highest plant height (140.0 cm) and plant spread (127.9 cm) was obtained with the application of VC and FYM, respectively which was at par with GM with sun hemp. These observations corroborated with the findings of Trivedi et al. (2012) in guava. Organic manures being bulky in nature, released soil compaction and improve soil aeration in addition to the supply of essential plant nutrients and organic matter, and thereby increasing the soil's biological activities. Earlier, increased release of growth factors like auxins, gibbrellins and cytokinin in root zone due to increased microbial inoculants in rhizospher soil was observed with the addition of various organics in pomegranate (Mir et al., 2015) and guava (Shukhla et al., 2009) orchards. It also provide room for better microbial establishment along with the accumulation of excess humus content (Hayworth et al., 1996). This might have enabled the plant to put up better vegetative growth. Increased growth of pomegranate (Saraf et al., 2004) and Litchi (Anubha Rani et al., 2013) plants was observed with the application of 10 and 150 kg FYM per plant, respectively.

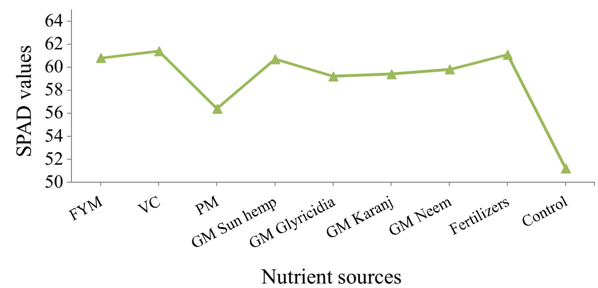

Fig. 1. Effect of organic nutrient sources on leaf chlorophyll content (SPAD).

Chlorophyll contents in the leaves of the plants as expressed by SPAD values significantly varied from 51.2 (control) to 61.4 (VC) amongst the treatments (Fig. 1). Application of FYM and GM with sun hemp was equally effective in increasing chlorophyll content in the leaves, indicating better photosynthetic capacity of the plants. The balanced and regular nutrient uptake by the plants increased availability and uptake of N, Mg and Fe, which play important role in chlorophyll formation (Shaahan et al., 1999). However, drastic reduction in leaf chlorophyll contents was recorded in control, that substantiate the role of balanced nutrition.

3.4. Fruit yield and quality

Various treatments of organic manuring had significant effect on fruit yield of pomegranate plants (Table 5). Application of PM

Table 3
Effect of organic nutrient sources on leaf nutrient contents (3 years pooled data).

Treatments	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
	(%)					(mg kg^{-1})			
FYM	2.33^{A}	0.178^{AB}	1.01^{AB}	1.96	0.43	166.6^{ABC}	32.7	77.7	44.5^{AB}
VC	2.27^{A}	0.149^{BC}	0.84^{CD}	1.65	0.47	158.7^{ABC}	27.1	77.7	44.3^{B}
PM	2.11^{A}	0.182^{A}	1.06^{A}	1.83	0.50	176.7^{A}	32.5	86.8	48.3^{AB}
GM Sun hemp	2.24^{A}	0.144^{C}	1.01^{AB}	1.69	0.48	169.9^{AB}	31.6	74.6	50.2^{A}
GM Glyricidia	2.15^{A}	0.137^{C}	0.92^{ABCD}	1.79	0.47	170.2^{AB}	32.3	88.5	45.8^{AB}
GM Karanj	2.10^{A}	0.142^{C}	0.93^{ABCD}	1.62	0.44	159.7^{ABC}	34.0	77.2	47.1^{AB}
GM Neem	2.08^{A}	0.143^{C}	0.89^{BCD}	1.86	0.43	166.7^{ABC}	29.9	79.7	45.4^{AB}
Inorganic fertilizers	2.17^{A}	0.146^{C}	0.96^{ABC}	1.82	0.49	150.5^{BC}	29.3	89.2	45.4^{AB}
Control	1.64^{B}	0.135^{C}	0.79^{D}	1.74	0.45	146.5^{C}	29.2	79.0	43.7^{B}
General Mean	2.12	0.15	0.93	1.77	0.46	162.8	30.9	81.1	46.1
CV(%)	6.54	6.76	5.6	8.9	14.7	4.9	12.9	18.6	4.3
SE(d)	0.11	0.01	0.04	0.13	0.05	6.49	3.2	12.3	1.6
Tukey's HSD at 5%	0.40	0.033	0.15	NS	NS	23.1	NS	NS	5.8

FYM – farm yard manure, VC – vermicompost, PM – poultry manure, GM – green manuring.
Means sharing a common letter within the column are not significant by Tukey's HSD test at $P < 0.05$.

Table 4
Effect of organic nutrient sources on vegetative growth of the plants during different years.

Treatments	2009		2010		2011[a]		2012[b]	
	Plant height (cm)	Average Plant spread (cm)	Plant height (cm)	Average Plant spread (cm)	Plant height (cm)	Average Plant spread (cm)	Plant height (cm)	Average Plant spread (cm)
FYM	175.3	152.4	235.9^{AB}	228.5^{A}	117.4^{AB}	116.1	133.6^{AB}	127.9^{A}
VC	176.4	152.6	240.5^{AB}	228.9^{A}	128.7^{A}	111.4	140.0^{A}	126.1^{A}
PM	176.2	154.6	233.8^{AB}	219.1^{A}	117.0^{AB}	113.6	125.0^{AB}	121.1^{AB}
GM Sun hemp	172.2	156.1	245.9^{A}	236.5^{A}	125.8^{A}	125.1	127.3^{AB}	123.2^{A}
GM Glyricidia	174.4	142.4	240.2^{AB}	220.7^{A}	117.3^{AB}	116.3	126.7^{AB}	119.2^{AB}
GM Karanj	170.0	148.7	238.2^{AB}	223.0^{A}	118.3^{AB}	114.5	124.2^{AB}	116.7^{AB}
GM Neem	172.6	150.3	225.7^{AB}	221.6^{A}	124.1^{A}	116.0	125.6^{AB}	121.1^{AB}
Inorganic fertilizers	178.9	160.5	248.0^{A}	238.4^{A}	123.1^{A}	121.1	129.0^{AB}	123.9^{A}
Control	164.4	135.5	210.5^{B}	192.7^{B}	102.5^{B}	100.9	115.8^{B}	106.7^{B}
General Mean	173.4	150.3	235.4	223.3	119.4	115.0	127.4	120.6
CV(%)	6.0	7.8	4.9	3.7	5.8	7.3	5.1	4.4
SE(d)	8.4	9.6	9.5	6.7	5.7	6.9	5.3	4.4
Tukey HSD at 5%	NS	NS	33.7	23.9	20.1	NS	18.9	15.5

FYM – farm yard manure, VC – vermicompost, PM – poultry manure, GM – green manuring means sharing a common letter within the column are not significant by Tukey's HSD test at $P < 0.05$.

[a] Re-growth after cutting of the plants to ground level due to disease infestation.
[b] After uniform pruning for induction of flowering and fruiting of the plants.

Table 5
Effect of organic nutrient sources on yield and quality of the fruits.

Treatments	No. of fruits plant^{-1}	Fruit weight (kg plant^{-1})	Average fruit weight (g)	Fruit juice (%)	Juice acidity (%)	TSS (°Bricks)	TSS: acid ratio
FYM	26.3^{AB}	3.86^{A}	146.8^{BC}	41.5^{ABC}	0.43^{AB}	15.07^{AB}	35.0^{AB}
VC	15.0^{C}	2.18^{B}	145.0^{BC}	40.8^{C}	0.37^{B}	15.13^{AB}	40.6^{A}
PM	29.7^{A}	3.96^{A}	133.8^{C}	43.8^{AB}	0.41^{AB}	15.53^{AB}	38.3^{AB}
GM Sun hemp	19.7^{BC}	2.97^{AB}	150.9^{BC}	44.0^{A}	0.44^{AB}	15.80^{A}	36.2^{AB}
GM Glyricidia	15.3^{C}	2.38^{B}	155.1^{AB}	43.3^{ABC}	0.42^{AB}	15.33^{AB}	36.6^{AB}
GM Karanj	14.7^{C}	2.03^{B}	137.7^{BC}	41.3^{BC}	0.45^{A}	15.20^{AB}	33.6^{B}
GM Neem	17.7^{BC}	2.75^{AB}	155.9^{AB}	43.7^{AB}	0.46^{A}	15.40^{AB}	33.5^{B}
Inorganic fertilizers	18.3^{BC}	3.15^{AB}	172.0^{A}	43.0^{ABC}	0.42^{AB}	14.60^{B}	35.2^{AB}
Control	13.0^{C}	1.88^{B}	144.2^{BC}	43.6^{AB}	0.39^{AB}	14.80^{AB}	38.2^{AB}
General Mean	18.9	2.80	149.0	42.8	0.42	15.21	36.3
CV(%)	16.8	17.18	4.3	2.2	6.31	2.46	6.3
SE(d)	2.6	0.392	5.2	0.75	0.022	0.306	1.9
Tukey HSD at 5%	9.22	1.40	18.5	2.67	0.08	1.09	6.6

FYM – farm yard manure, VC – vermicompost, PM – poultry manure, GM – green manuring.
Means sharing a common letter within the column are not significant by Tukey's HSD test at $P < 0.05$.

recorded highest fruit yield (3.958 kg plant^{-1}) at par with FYM (3.86 kg plant^{-1}). In PM and FYM treatments, increase in yield was 25.5 and 22.3%, higher than inorganic fertilizers, respectively while, as compared to control it was 110.7 and 105.3% higher, respectively. Nutrients in organic manures were released slowly and made available throughout the growth period and resulted in better uptake of nutrients, plant vigor and yield of the plants. Increased microbial population and better soil physical environment could have facilitated easy absorption of nutrients in balanced form which translated into increased yield. There was significant and positive correlation between fruit yield of sweet orange and increased content of available N, P and K with the application of different organic manures (Marathe and Bharambe, 2007). Higher residual effect of

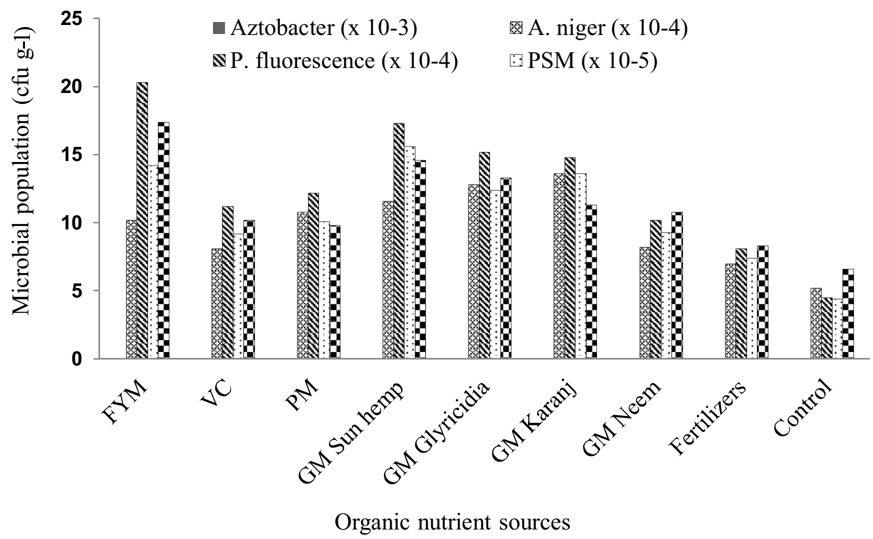

Fig. 2. Effect of organic nutrient sources on soil microbial population.

green manures and FYM were reported by Sharma et al. (2005) in litchi and Garhwal et al. (2014) in kinnow mandarin crops.

Most of the organic manuring treatments were significantly effective to improve quality of fruits in terms of fruit juice, juice acidity, total soluble solids (TSS) and TSS:acidity ratio in fruit juice (Table 5). Improved fruit quality response as assessed by the highest juice recovery (44.1%) and TSS (15.8 °Bricks) was observed in the fruits of the plants supplied with GM with sun hemp followed by PM. The lowest fruit juice acidity (0.37) and highest TSS:acid ratio (40.6) was recorded in VC treatment. However, the influence of different treatments on fruit rind, fruit aril fruit height, fruit diameter and rind thickness was non-significant (Data not shown). In general quality of the juice of the fruits produced with the application of organic manure was better as compared to inorganic fertilizer. Increased fruit quality of pomegranate with the increased leaf K levels was reported under south Indian conditions (Muthumanickam and Balakrishnamoorthy, 1999). Application of 90 kg FYM per plant has earlier improved quality parameters of kinnow mandarin (Garhwal et al., 2014).

3.5. Soil microbial population

All organic manures were highly effective in increasing microbial population as compared to inorganic fertilizers and control. Maximum *Pseudomonas fluorescence* (20.3×10^{-4} cfu g^{-1}) and *Azotobacter* (17.4×10^{-3} cfu g^{-1}) population was recorded with FYM (Fig. 2). It was observed that green manures acts as an excellent subtract for soil microbes in increasing their population. GM with sun hemp recorded maximum potash solubilising organisms (15.6×10^{-5} cfu g^{-1}) count. Population of *Aspergillus niger* was the highest with *ex situ* green manuring with Karanj (13.6×10^{-4} cfu g−1) followed by glyricidia (12.8×10^{-4} cfu g^{-1}). Higher amount of decayed material available from the chopped loppings of these plants helped the microbes specially fungal colonies to multiply rapidly recorded highest *Aspergillus niger* count. These observations supplemented the fact that these microbes multiply well in pomegranate orchard soil and their efficiency to multiply in the presence of organic matter was comparatively higher, due to greater availability of organic carbon and mineralized nutrients for their proliferation and further cellular developments (Marathe et al., 2011). The beneficial effect due to increased population of soil microbes like bacteria (Tiwari et al., 2001) fungus (Naranjane et al., 1993) and actinomycetes (Patil and Varade, 1998) by the application of organic manures and green manures has been a well established fact.

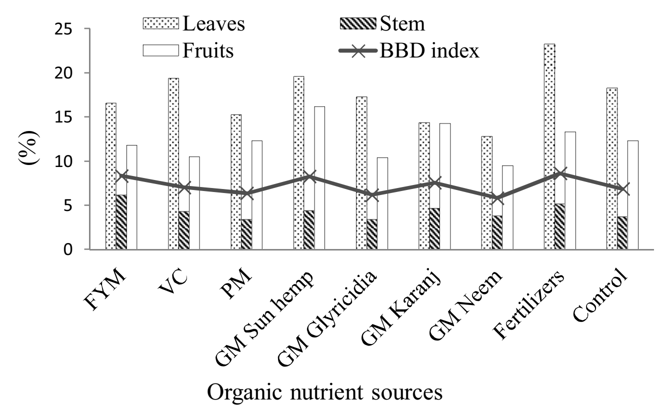

Fig. 3. Effect of organic nutrient sources on bacterial blight disease (BBD) incidence on various plant parts.

3.6. Diseases incidence

Prevalence of bacterial blight disease (BBD) was observed on almost all the plants under experimentation. Incidence of BBD on leaves, stem and fruits varied from 12.8 to 23.3, 3.4 to 6.2 and 9.5 to 16.2%, respectively under different treatments (Fig. 3). The highest disease incidence on leaves was observed in inorganic fertilizers followed by GM with sun hemp. Similarly, BBD incidence on fruits was highest under GM with sun hemp. The sun hemp plants grown near the plants might have increased humidity in the microclimate of the plants which resulted into increased incidence of the disease. Yadessa et al. (2010) found higher disease severity in soil amended with 10% green compost compared to the control treatment. Disease incidence on stem did not show and fixed trend amongst the treatments. Green manuring with neem was effective treatment and recorded the lowest BBD incidence on leaves (12.8%) and fruits (9.5%). Results on BBD index revealed that disease incidence was high in GM with sun hemp (*insitu*) followed by inorganic fertilizer. It was the lowest in by GM with neem followed by GM with glyricidia and PM treatments. Earlier, Yadessa et al. (2010) reported complete suppression of bacterium *Ralstonia solanacearum* in pots amended with FYM. Similarly, Chatterjee and Khalko (2013) reported higher levels of vermicompost as better organic nutrient source over that of FYM and inorganic fertilizers alone in reducing late blight of tomato and giving higher marketable yields. The humic acid and humic substances of vermicompost probably provide growth promoting substances, vitamins and enzymes which are not available in sole inorganic fertilizers and these probably have increased the plant resistance to pathogen. The suppressive effect of compost is predominantly biological (Joshi et al., 2009). Many beneficial microorganisms produce metabolites/enzymes in the rhizosphere of the plant which are translocated to the plant system and impart systemic resistance to plant, thus reducing losses due to aerial pathogens.

4. Conclusions

The results of this study unravelled that the nutritional requirement of pomegranate could be fulfilled with the exclusive use of organic sources without affecting growth performance and yield. Maximum fruit yield (3.958 kg plant^{-1}) was obtained with PM which was 110.8% more than that of control and 25.5% with inorganic fertilizer application. Plants supplied with PM recorded balanced uptake of all the major and micronutrients. FYM which is easily available was also very effective for improving soil organic carbon (1.18%) and thereby increasing soil fertility status with respect to available P (64.4 kg ha^{-1}), K (578.7 kg ha^{-1}), Cu (15.1 mg kg^{-1}) Zn (2.30 mg kg^{-1}) and Mn (8.4 mg kg^{-1}) in the soil. Amongst various green manures, sun hemp was very effective in producing fruit yield (3.153 kg plant^{-1}). With the use of GM with sun hemp, the microbial load of soil has also increased 3 to 4 folds, which would translate into higher soil fertility. However, *insitu* green manuring should be used with periodical monitoring for bacterial blight disease infestation. Considering medicinal and nutraaceticual importance of pomegranate, organic manure is very important for ensuring better soil health and sustained crop production with improved fruit quality. It can be concluded that organic sources *viz.* farmyard manure, poultry manure and green manuring with sun hemp could be harnessed for effective organic production of the pomegranate.

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