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Research Articles

Standardization of organic manure application in pomegranate (*Punica granatum*) orchards grown in semi-arid regions

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ABSTRACT

An experiment was conducted at ICAR - National Research Centre on Pomegranate during 2011-12 and 2012-13 on pomegranate (*Punica granatum* L) cv. Bhagwa plants. The experiment comprises of application of raw and well decomposed farmyard manure in the form of slurry (liquid form, manures mixed with water in 1:10 ratio and kept for 10 to 15 days with intermittent stirring) as a sole or in combination with micronutrients and/or various microbial inoculants. It was compared with normally practiced method of organic manure application in the soil. The results revealed that application of farmyard manure in slurry form decreased electrical conductivity (0.94 to 0.72 dS/m) and increased organic carbon content (0.55 to 1.45 %) in the soil. Combined application of FYM in the form of slurry along with micronutrients and microbial inoculants significantly increased available N (339.7 kg/ha) and P (34.8 kg/ha) and micronutrients content in the soil. Substantially increased plant height (20.8 %), plant spread (22.8 %) and produced maximum number of fruits (39.0/ plant). Population of soil microbes, viz. *Aspergillus niger*, *Pseudomonas fluorescence* and potash solubilising organisms were significantly highest with the combined application of FYM in slurry form and microbial inoculants. While, *Azotobacter* population was more in raw FYM slurry along with microbial inoculants. It is recommended that on light textured soils, farmyard manures should be applied in the form of slurry. It reaches in the active root zone of the plants along with percolating water.

Key words: Application method, Microbial inoculants, Nutrient uptake, Organic manures, Pomegranate, Slurry form, Yield

Pomegranate (*Punica granatum* L.) is an economically important fruit crop of arid regions due to its hardy nature and adaptability to varied climatic conditions. In India, it is cultivated over 1.13 lakh ha with an annual production of 7.44 lakh tonnes having productivity of 6.6 tonnes/ha which is low as compared to other leading countries. Majority of the pomegranate growing areas have nutrient deficient, shallow, gravelly soils with low organic matter and fertility status (Marathe *et al*. 2006). For the improvement of soil organic carbon and soil health it is necessary to apply organic manures which are scarcely available in the region. At present, farmers are applying organic manures in most unscientific manner. In most of the cases it is raw, undecomposed and placed above the soil surface in the form of heaps or simply dumped below the plant canopy. It is not reaching in the root zone of the plants and hence major portion of organics remained unutilized due to lack of moisture and lead to loss of N, P and K to the extent of 30-35 %, 20-25 % and 4-6 %, respectively due to leaching, washing and volatilization (Singh 2000). Hence, an experiment was conducted to standardise an efficient method of application of organic manures directly in the root zone of pomegranate plants grown under light textured soils.

MATERIALS AND METHODS

A field experiment was conducted during the years 2011-12 and 2012-13 on bearing pomegranate cv. Bhagwa plants at the research farm of National Research Centre on Pomegranate, Solapur, Maharashtra (17^{o}65'' N and 75^{o}90'' E, 457 m above msl). The climate of the study area was semi-arid with an average annual rainfall of 694 mm occurring mostly during the months of July-September. Some important properties of experimental soil were as follows: pH 7.86, electrical conductivity 0.94 dS/m, organic carbon 0.35 %, calcium carbonate 14.4 %, available N 210.3 kg/ha, available P 11.9 kg/ha, available K 250.7 kg/ha and available micronutrients, viz. Fe, Mn, Cu and Zn content was 3.94, 3.4, 3.02 and 3.54 ppm, respectively.

The experiment comprises of application raw and decomposed farmyard manure (FYM) in the form of slurry (liquid form, manures mixed with water in 1:10 ratio and kept for 10 to 15 days with intermittent stirring) as a sole

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or in combination with micronutrients ($FeSO_4$, $MnSO_4$ and $ZnSO_4$, 50 g each/plant/year) and/or microbial inoculants [Symbion-*VAM/Glomus fasciculatum*, Kalisena (*Aspergillus niger*, AN- 27), *Trichoderma viridi*, *Azotobacter crocoum*, PSB, *Pseudomonas* species and Potash Mobilizing Bacteria]. Similarly, as a standard practice, well decomposed farmyard manure was applied as a soil application. The experiment was laid out in randomised block design with 13 treatments, 3 replications having 4 plants/unit. The treatments were soil application of T_1: well decomposed FYM as normal practice; T_2: well decomposed FYM in the form of slurry; T_3: raw FYM in the form of slurry; T_4: well decomposed FYM as normal practice + micronutrients; T_5: well decomposed FYM in the form of slurry + micronutrients; T_6 : raw FYM in the form of slurry + micronutrients; T_7: well decomposed FYM as normal practice + microbial inoculants; T_8: well decomposed FYM in the form of slurry + microbial inoculants; T_9: raw FYM in the form of slurry + microbial inoculants; T_{10}: well decomposed FYM as normal practice + micronutrients + microbial inoculants; T_{11}: well decomposed FYM in the form of slurry + micronutrients + microbial inoculants; T_{12}: raw FYM in the form of slurry + micronutrients + microbial inoculants and T_{13}: Control.

Soil samples were collected at the start and end of the experiment, dried and analyzed to determine physico-chemical properties and fertility status using standard procedures (Jackson 1973). Chlorophyll content in the leaf as indicated by SPAD values was measured using chlorophyll meter (KONICA MINOLTA SPAD-502). At the end of the experiment, count of various microorganisms, viz. *Aspergillus niger, Pseudomonas fluorescence,* Potash solubilizing organisms and *Azotobactor* were measured using Rose Bengal Agar Base, King's B, Aleksandrov agar and *Azotobacter* agar (Mannitol) medias, respectively (Whitman 2010). 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 and fruit weight basis and analyzed for different quality parameters (Anonymous 1995). Data obtained from the experiment were analysed statistically using analysis of variance (ANOVA). Significance of difference among the treatments effects was tested through 'F' test and critical difference were calculated wherever the results were significant (Panse and Sukhatme 1989).

RESULTS AND DISCUSSION

Soil physicochemical properties

There was significant decrease in soil electrical conductivity from 0.94 to 0.72 dS/m with the combined application of FYM slurry + microbial inoculants (Table 1). Similarly considerable decrease in soil pH and $CaCO_3^{--}$ from 7.86 to 7.70 and 14.4 to 10.5%, respectively, was observed with the application of FYM slurry but the results were non-significant. Almost all the treatments of organic manuring decreased soil pH, EC and $CaCO_3$ in the soil over control. The lowering of pH values might be due to acidifying effect of organic acids produced during the course of decomposition of farmyard manure. While lowering of EC and $CaCO_3$ values under these treatments is ascribed to the increased permeability and consequent leaching of salts (Srikant *et al.* 2000). The organic carbon content showed large variation (0.55 to 1.45) and was significant highest with the combined application of FYM + micronutrients + microbial inoculants. This could be attributed to the addition of organic matter and better root and shoot growth of the plant. The manures itself also contributed partially in increasing the organic carbon of the soil (Bhriguwanshi 1988). Method of application of FYM in slurry form was more effective in increasing organic carbon content in soil as it was very well distributed in rooting zone of the plant.

Table 1 Soil properties as influenced by different methods of manure application

Treatment	pH	EC (dS/m)	Organic carbon (%)	Calcium carbonate (%)
FYM, normal practice	7.73	0.72	0.90	13.0
FYM slurry	7.70	0.90	1.05	11.9
Raw FYM, slurry	7.78	0.78	1.06	12.5
FYM + micronutrients	7.80	0.85	0.90	13.9
FYM slurry + micronutrients	7.70	0.94	0.98	14.1
Raw FYM slurry + micronutrients	7.78	0.85	1.05	11.6
FYM + microbial inoculants	7.75	0.77	0.98	13.2
FYM slurry + microbial inoculants	7.71	0.90	1.20	13.1
Raw FYM slurry + microbial inoculants	7.80	0.94	1.35	13.1
FYM + micronutrients + microbial inoculants	7.70	0.78	1.20	11.8
FYM slurry + micronutrients + microbial inoculants	7.75	0.80	1.35	10.5
Raw FYM slurry + micronutrients + microbial inoculants	7.80	0.90	1.45	12.1
Control	7.83	1.03	0.55	14.4
CD (P=0.05)	NS	0.15	0.306*	NS

Soil nutrients status and chlorophyll content

Among the major nutrients, available N (339.7 kg/ha) and P (34.8 kg/ha) increased significantly with the combined application of FYM slurry + micronutrients + microbial inoculants (Table 2). The farmyard manure contains appreciable quantity of P (0.45%) and K (0.76%). The process of mineralization due to increased biological activities might have increased their availability in soil. The acidulation effect of farmyard manure on applied and native P also enhanced the P availability (Prakash *et al*. 2002). The observations also revealed that the treatments involving use of microbial inoculants recorded higher N (298.4 to 339.7

Table 2 Soil nutrient status as influenced by different methods of manure application

Treatment	Available macronutrients (kg/ha)			Available micronutrients(ppm)			
	N	P	K	Fe	Mn	Cu	Zn
FYM, normal practice	318.7	30.2	370.7	5.81	12.27	7.00	6.11
FYM slurry	327.7	34.3	380.8	6.93	14.03	7.98	5.20
Raw FYM, slurry	298.4	31.6	405.4	5.53	10.77	6.41	5.39
FYM + micronutrients	301.1	25.7	376.0	5.51	13.03	4.86	6.05
FYM slurry + micronutrients	331.0	29.6	325.5	6.15	15.80	5.86	5.64
Raw FYM slurry + micronutrients	328.6	30.0	300.4	5.11	15.03	6.08	4.80
FYM + microbial inoculants	309.7	28.5	409.5	4.79	13.00	4.89	4.50
FYM slurry + microbial inoculants	307.8	32.1	489.3	4.20	13.83	3.55	6.26
Raw FYM slurry + microbial inoculants	280.1	32.6	470.9	4.18	10.17	4.85	5.85
FYM + micronutrients + microbial inoculants	317.9	24.8	340.4	5.24	15.03	6.24	6.01
FYM slurry + micronutrients + microbial inoculants	339.7	34.8	436.4	6.25	14.40	5.51	6.20
Raw FYM slurry + micronutrients + microbial inoculants	303.8	30.3	442.6	6.10	12.23	4.43	5.66
Control	204.8	11.1	238.3	3.75	3.72	3.30	3.08
CD (P=0.05)	34.76*	6.80*	30.08*	0.37*	2.34*	0.84*	0.48*

kg/ha) and P (28.5 to 34.8 kg/ha) than those corresponding treatments (28.1 to 327.7 kg/ha N and 24.8 to 32.1 kg/ha P) where only FYM was applied as a sole or along with micronutrients. These observations clearly indicated the role of microbes *Aspergillus niger* and *Azotobacter chrococcum* in associative N-fixation and increased decomposition by *Trichoderma viridi*. The significant role of biofertilizers in enhancing the nutrient supply was also reported by Bhattacharya (1999) in fruit crops and Marathe *et al*. (2011) in pomegranate. Highest content of available K (489.3 kg/ha) was with the application of FYM slurry in combination with microbial inoculants. Increased K availability is attributed to direct addition of K through organic manure and solubilisation of K by organic acids besides the reduction in K fixation and release of K due to interaction of organic matter with clay (Bellakki *et al*. 1998).

The DTPA extractable micronutrients, viz. Fe, Cu and Zn showed significant variation due to different treatments. The increase in soil micronutrients content in almost all the manuring treatments were several fold as compared to control plants. Increase was mainly due to addition of organic manure which contains considerable amount of micronutrients. Results further revealed that microbial inoculants played very important role in increasing micronutrients content in the soil. Incorporation of microbial inoculants as a sole or its combination with micronutrients was more effective than micronutrients alone. Increased availability of micronutrients by various microorganisms as *A. brasilence* + *P. strita* (Ghazi 2006) *P. fluorescence* and PPFM in pomegranate (Marathe *et al*. 2011) was reported earlier. The increase might be due to production of growth promoting substances (Gyaneshwar *et al*. 2002) and production of nutrient solubilising enzymes. There was general perception that application of raw FYM along with micronutrients was more effective due to chelation effects. On the contrary, the results confirmed that application of well decomposed manure slurry was effective in increasing availability of micronutrients in soil.

The chlorophyll content in the leaves (SPAD values) was significantly highest with the combined application of well decomposed FYM slurry + micronutrients + microbial inoculants followed by its soil application (Table 3). This might be due to increased availability and uptake of N, Mg and Fe (Table 2) which have important role in chlorophyll formation (Shaahan *et al*. 1999). Chlorophyll content was low in the treatments involving application of raw FYM. This might be due to immobilization of soil nutrients affecting leaf chlorophyll content adversely.

Soil microbial population

Population of soil microbes, viz. *Aspergillus niger*, *Pseudomonas fluorescence* and potash solubilising organisms significantly varied from 4.00 to 12.67 × 10^{-4}, 3.33 to 20.0 × 10^{-5}, and 3.67 to 15.67 × 10^{-5} cfu/g soil, respectively amongst the treatments (Table 3) and was the highest with the application of FYM in slurry form + microbial inoculants, while *Azotobacter* (4.0 to 17.33 × 10^{-5} cfu/g soil) population was highest with the application of raw FYM slurry + microbial inoculants. Treatments involving inoculation of microbial inoculants in FYM increased their abundance in the soil compared to control plots. These observations supplemented the fact that inoculated microbes multiply well in pomegranate orchard soil and their efficiency to multiply in presence of organic matter was comparatively high, due to greater availability of organic carbon and mineralized nutrients for their proliferation and further cellular developments. The beneficial effect of organic manures to build up microbial population was earlier reported by many workers (Sharma *et al.* 1983, Kukreja *et al.* 1991, Patil and Raut 2002). Incorporation of microbial inoculants was equally effective in decomposed as well as raw FYM in increasing microbial population in the soil. Substantial microbial population was also recorded with the application of FYM alone in the form of slurry. Surprisingly, mixing of

Table 3 Leaf chlorophyll content and soil microbial population as influenced by different methods of manure application

Treatment	Leaf chlorophyll content(SPAD)	Microbial population in the soil (cfu/g)			
		Aspergillus niger $\times 10^{-4}$	*Pseudomonas fluorescence* $\times 10^{-5}$	Potash solubilizing organisms $\times 10^{-5}$	*Azotobacter* $\times 10^{-5}$
FYM, normal practice	59.53	6.0	5.0	8.33	10.67
FYM slurry	59.99	6.67	8.0	6.67	5.0
Raw FYM, slurry	58.52	4.67	4.0	4.0	10.33
FYM + micronutrients	59.90	5.33	4.67	3.67	10.67
FYM slurry + micronutrients	60.67	8.33	4.0	8.0	13.33
Raw FYM slurry + micronutrients	59.23	8.0	4.33	10.67	11.33
FYM + microbial inoculants	60.45	8.67	12.33	8.00	8.33
FYM slurry + microbial inoculants	59.64	12.67	20.0	15.67	10.0
Raw FYM slurry + microbial inoculants	58.76	12.33	8.33	14.0	17.33
FYM + micronutrients + microbial inoculants	60.80	6.00	6.00	8.33	6.67
FYM slurry + micronutrients + microbial inoculants	61.54	4.0	4.33	9.0	8.33
Raw FYM slurry + micronutrients + microbial inoculants	60.16	6.67	3.33	7.33	6.67
Control	58.34	4.33	4.0	6.67	4.0
CD (P=0.05)	1.53*	2.99*	2.58*	3.87*	6.62

micronutrients exerted little response in increasing microbial population, rather it adversely affected population of *Aspergillus niger*, *Pseudomonas fluorescence* and potash solubilising organisms except *Azotobacter* which recorded increased population.

Plant vegetative growth

Vegetative growth of the plant as indicated by plant height and plant spread revealed significant increase in organic manuring treatments compared to control plants (Table 4). With the combined application of well decomposed FYM in slurry form + micronutrients + microbial inoculants, significantly highest increase in plant height and plant spread was 12.9 and 15.3 %, respectively, during first year which increased substantially to 20.8 and 22.8 % during second year. Increased soil fertility, physical properties coupled with microbial population is being reflected in terms of increased growth of the plants over control plants. Beneficial effects of organics along with inorganic fertilizers and biofertilizers were reported earlier by Singh (2009) and

Table 4 Plant growth, flowering and Fruit yield as influenced by different treatments of manure application

Treatment	Percent increase during 2011-12		Percent increase during 2012-13		Male flowers/ plant	Hermaphrodite flowers/ plant	No. of fruits/ plant	Wt. of fruits/ plant (kg)
	Plant height	Plant spread	Plant height	Plant spread				
FYM, normal practice	10.4	11.0	16.9	17.1	130.4	76.8	25.5	3.847
FYM slurry	10.9	11.6	17.3	17.5	144.2	69.5	31.1	4.899
Raw FYM, slurry	9.5	9.4	15.8	15.7	181.9	90.7	20.6	3.582
FYM + micronutrients	10.0	11.1	16.4	16.9	124.8	73.7	18.1	3.769
FYM slurry + micronutrients	10.6	11.2	15.6	17.1	135.7	75.6	32.0	5.240
Raw FYM slurry + micronutrients	9.8	8.8	14.7	15.9	175.9	82.3	23.3	3.605
FYM + microbial inoculants	10.9	10.9	17.2	17.4	150.8	76.8	26.0	4.374
FYM slurry + microbial inoculants	11.6	11.5	17.9	17.9	144.9	81.2	37.1	6.615
Raw FYM slurry + microbial inoculants	9.9	10.6	15.0	16.2	174.2	76.4	22.0	4.592
FYM + micronutrients + microbial inoculants	12.4	14.1	18.8	21.4	145.2	68.0	25.2	4.505
FYM slurry + micronutrients + microbial inoculants	12.9	15.3	20.0	22.8	154.4	73.9	39.0	6.681
Raw FYM slurry + micronutrients + microbial inoculants	11.1	11.0	17.5	19.3	152.3	78.2	28.0	4.740
Control	9.2	9.3	11.4	12.5	166.6	65.4	15.1	2.683
CD (P=0.05)	1.50*	1.3	3.33*	2.01*	7.86*	4.83*	3.20*	0.391*

Sharma *et al*. (2009) in pomegranate and Marathe and Bharambe (2007) in citrus under varied climatic conditions. During first year, plant growth was adversely affected with the application of raw FYM. This might be due to its wide C:N ratio which immobilize soil nutrients during the process of decomposition, adversely affecting the plant growth (Singh 2000). During second year of study, plant growth was not adversely affected due to build up of organic carbon in soil. Microbial inoculation increased plants growth substantially, but the results were visible after six months. Incorporation of micronutrients alone was not much effective in increasing plant growth. This might be due to the fact that the farmyard manure itself contains substantial amount of micronutrients, sufficient to meet the requirement of the plants. Application of manure in the form of slurry was very effective in increasing the growth of the plants.

Flowering and fruit yield

Flowering intensity, indicated as male and hermaphrodite flowers showed highly significant variation amongst the treatments (Table 4). Intensity of male flowers showed large variation (135.7 to 181.9) as compared to hermaphrodite flowers (73.7 to 90.7). Highest number of male and hermaphrodite flowers were produced with the application of raw FYM in the form of slurry. Treatments involving application of raw FYM in combination with micronutrients or microbial inoculants were also equally effective. With the application of raw FYM in soil, decomposition process activates which immobilize soil nutrients and provides stress in the plants, required for flowering induction under central Indian climatic conditions (Marathe and Jadhav 2010).

Fruit yield in terms of number of fruits revealed large variation (15.1 to 39.0/ plant) amongst the treatments and was significantly highest in the plants receiving combined application of well decomposed FYM in the form of slurry along with micronutrients and microbial inoculants (Table 4). Results on similar line were earlier reported by Meena *et al*. (2009). Slurry application of cow dung manures was far better than normal method of manure application in increasing fruit yield. Though flowering intensity was high (230.5 to 265.2 /plant) with the application of raw FYM, it does not reflected in producing fruit yield and was considerably low (20.6 to 28.0 /plant) in raw FYM application treatments.

The present study demonstrated that, application of organic manures in slurry/liquid form (organic manure + water in 1:10 ratio, kept for 10 to 15 days with intermittent stirring) was the most effective and efficient method of organic manure application for pomegranate orchards grown under light textured soils. In this method, organic manures slurry reached to active root zone along with percolating water, thereby, improving soil physical conditions, aeration, microbial activities and nutrient availability to the plants. In this method, raw organic manure if any, get completely decomposed at the time of incubation. Various micronutrients can be added in the slurry which slowly made available to the plants due to chelation effects. Substantially increased microbial population in the soil helped to fixed atmosphere nitrogen and solubilise fixed nutrients in the soil.

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