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Effect of different water regimes and organic manures on quality parameters of noni (*Morinda citrifolia*)

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An experiment was conducted in *Morinda citrifolia* to find out the suitable water regime along with organic manure schedule for obtaining superior quality fruits. The experiment was carried out in split plot design with irrigation regimes on main plot (four levels) and organic manures on sub plot (eight levels) with two replications. Among the interaction, M_2S_4 (100% crop water requirement through drip irrigation + 50% farmyard manure + 50% vermicompost) recorded the highest scores for pulp recovery (47.12%), juice recovery (34.32%), TSS (11.26^o brix), ascorbic acid (197.82 mg/100 g), titrable acidity (0.392%), fruit firmness (3.26 kg/cm^2), total carbohydrate (584.39 mg/100 g), total phenol (374.26 mg/100 g), total carotenoids (0.177 mg/100 g), protein (412.95 mg/100 g) and total flavonoids (128.53 mg/100 g) content of noni fruits.

Key words: *Morinda citrifolia,* drip irrigation, farmyard manure (FYM), vermicompost, quality, carotenoids, flavonoids, protein.

INTRODUCTION

Medicinal plants are nature's priceless gift to human beings. The demand for plant based raw materials for pharmaceuticals is increasing tremendously. Today's health care systems rely largely on plant material. Most of the world's population depends on traditional medicine to meet daily health requirements, especially within the developing countries, where plants are the main source of medicine (Meena et al., 2009).

Over the past few years as natural products have become increasingly popular, the field of natural herbal remedies have flourished. One upcoming botanical name, the fruit of *Morinda citrifolia* very popularly known as NONI belongs to the family Rubiaceae.

Noni is the biggest pharmaceutical unit in the universe because it has more than 160 nutraceuticals, vitamins, minerals, micro and macro nutrients that help the body in various ways from cellular level to organ level (Rethinam and Sivaraman, 2007). The fruit juice is in high demand in alternative medicine for different kinds of illnesses such as arthritis, diabetes, high blood pressure, muscle aches, menstrual difficulties, headaches, heart disease, AIDS, cancers, gastric ulcers, sprains, mental depression, senility, poor digestion, atherosclerosis, blood vessel problems and drug addiction (Wang et al., 2002).

The purpose of this medicinal herb will be fulfilled only if it is free from residual effects due to chemical farming. Otherwise the herb will become toxic than of medicinal value. Moreover, the medicinal plants have several active biochemical ingredients, which may get altered and deteriorated quality wise, when grown with the use of inorganic fertilizers and pesticides.

Continuous and unscrupulous use of fertilizers, pesticides and fungicides without the incorporation of organic manure cause environmental degradation especially, in

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the soil thereby affecting its fertility on long term basis. For maintaining optimum productivity of the land and building up of soil fertility, the addition of organic manures to crops has been suggested as one among the recommendation. Large scale cultivation under organic conditions is gaining momentum to produce toxic free medicinal plant products (Padmanabhan, 2003).

Organic agriculture is gaining importance and acceptance throughout the world with annual growth of 20 to 25% (Vanilarasu, 2011).

The availability of irrigation water is dwindling day-by-day. Adoption of conventional methods of irrigation to crops leads to an acute scarcity of water and results in reduced production and productivity of crops. Therefore, it becomes imperative to go for alternate water saving methods by more crop and income for every drop of water. Drip irrigation can be considered as an efficient irrigation system, since it causes wetting of the soil only and maintain optimum moisture content in the root zone. It also offers several water management advantages like timely application of water and water supply. Micro irrigation provides many unique agronomic, water and energy conservation benefits that address many of the challenges facing irrigated agriculture, now and in the future (Selvarani, 2009).

The water demand for ecological farming is far less and the crops grown using organic supplements and biological inputs are hardier and more drought tolerant than the ones grown with chemical inputs (Baby, 2012).

Hence, the study was undertaken to find out the best organic manure schedule along with irrigation system for production of noni fruits with supreme quality.

MATERIALS AND METHODS

This study was conducted at Horticultural College and Research Institute, TNAU, Periyakulam, Tamil Nadu, India which is situated at 77ºE longitude, 10ºN latitude and at an altitude of 300 m above mean sea level.

Methodology

The design as well as method used is as follows:

1. Statistical design: Split plot design
2. Factors: 2
3. Replications: 2
4. Spacing: 3.6 m × 3.6 m

Treatment details

The following are the treatment details for the main plot (irrigation):

M_1: 75% WRc (Crop water requirement through drip irrigation);
M_2: 100% WRc (Crop water requirement through drip irrigation);
M_3: 125% WRc (Crop water requirement through drip irrigation);
M_4: Check basin method of irrigation (once in 5 days)

The treatment details for the subplot (Organic manures) are as follows:

S_1: 100% farmyard manure (FYM);
S_2: 100% vermicompost (VC);
S_3: 100% coir pith compost (CPC)
S_4: 50% FYM + 50% VC
S_5: 50% FYM + 50% CPC;
S_6: 50% VC + 50% CPC;
S_7: 100% recommended dose of nitrogen (RDN) through inorganic fertilizers;
S_8: Control (no manures and no fertilizers);

All organic manures were applied on equivalent weight of RDN (60 g/plant/year - on N equivalent basis). The treatments S_1 to S_6 are applied with *Azospirillum* (10 g/ plant) + phosphobacteria (10 g/ plant) + VAM (20 g/ plant).

Crop water requirement (WRc)

Crop water requirement was calculated by using the following formula:

$WRc = P_e \times K_p \times K_c \times A \times WP$ L/plant/day

Where, P_e = Pan evaporation in mm; K_p = Pan Co-efficient (0.75); K_c = Crop factor (0.90 for vegetative stage, 0.95 for flowering and harvesting stage); A = Area occupied by the tree (3.6 m × 3.6 m); WP = wetted percentage (40).

Observations

Quality parameters

Pulp recovery: The pulp was separated from fully ripe fruits excluding peel and seeds and weighed and expressed in percentage.

Juice recovery: The juice was extracted from fully ripe fruits using hand pulper and expressed in percentage.

Total soluble solids (TSS): The TSS content of noni fruit was determined using a "Zeiss" hand refractometer. The readings were recorded as ^{o}brix after deducting the correction factor.

Ascorbic acid: The ascorbic acid content was estimated using the procedure of A.O.A.C. (1975) and expressed as mg/100 g of fresh sample.

Titrable acidity: The titrable acidity as percentage of citric acid was estimated following the method of A.O.A.C. (1975) and expressed in percentage.

Fruit firmness: Firmness of fruits was measured using a penetrometer (LT Lurton model FG 5000 A). Readings were taken at the proximal, distal and middle portions and the mean values were expressed as kilograms per square centimeter (kg/cm^2).

Total carbohydrate: Total carbohydrate was estimated by the method suggested Somogyi (1952) and expressed in mg/100 g.

Total phenol: Total phenol content of noni fruits was estimated by the method suggested by Bray and Thorpe (1954) using Folin Ciocalteu reagent and expressed as mg/100 g.

Total carotenoids: Total carotenoids were estimated by the method of Roy (1973) and expressed in mg/100 g.

Protein content: Protein content was estimated as per the A.O.A.C

Table 1. Effect of different water regimes and organic manures on pulp recovery (%) of noni fruits.

Treatments	M_1	M_2	M_3	M_4	Mean
S_1	37.86	40.71	40.36	35.78	38.68
S_2	38.04	42.14	42.31	36.23	39.68
S_3	37.08	39.28	39.13	35.15	37.66
S_4	38.56	47.12	43.65	36.34	41.42
S_5	37.14	39.79	40.10	35.27	38.08
S_6	37.29	41.87	41.53	35.94	39.16
S_7	38.23	41.02	41.15	36.11	39.13
S_8	34.14	34.29	34.51	31.27	33.55
Mean	37.29	40.78	40.34	35.26	38.42
	M	**S**	**M at S**	**S at M**	
SE(d)	0.209	0.275	0.555	0.549	
CD at 5%	0.664	0.563	1.225	1.125	

(1975) method and expressed in mg/100 g.

Total flavonoids: Total flavonoids were estimated by the method suggested by Singh et al. (2011) and expressed in mg/100 g.

Statistical analysis

The statistical analysis of data was done by adopting the standard procedures of Panse and Sukhatme (1985). The AGRES software (version 3.01) was used for analysis of data.

RESULTS

Pulp recovery

With regard to main plots, the treatment M_2 (100% WRc through drip irrigation) exhibited the highest pulp recovery of 40.78% while the treatment M_4 (check basin method of irrigation) recorded the lowest pulp recovery of 35.26% (Table 1). Between the sub plot treatments, S_4 (50% FYM + 50% VC) registered the highest pulp recovery of 41.42%. The pulp recovery was found to be the lowest in S_8 (no manures and no fertilizers) with 33.35%. The treatment combination, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) produced the highest pulp recovery of 47.12% and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with 43.65%. The pulp recovery was found to be the lowest (31.27%) in M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

Juice recovery

The main plot M_2 (100% WRc through drip irrigation) recorded the highest juice recovery of 28.14%. The treatment M_4 (check basin method of irrigation) registered the least score (24.02) for juice recovery percentage (Table 2). In the sub plot, the treatment S_4 (50% FYM + 50% VC) exhibited the highest juice recovery of 29.19% and this was followed by S_2 (100% VC) with 27.30%. The juice recovery of fruits was found to be the lowest in S_8 (no manure and no fertilizers) with 22.44%. In the interactions, the combination of the treatment M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) exhibited the highest juice recovery of 34.32% and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with 31.03%. The juice recovery was found to be the lowest in M_4S_8 (check basin method of irrigation + no manure and no fertilizers) with 21.09%.

TSS

Among the main plot treatments, M_2 (100% WRc through drip irrigation) registered the highest score for TSS with 10.13^o brix and this was on par with M_3 (125% WRc through drip irrigation) with TSS content of 10.06^o brix (Table 3). While the treatment M_4 (check basin method of irrigation) noticed the lowest score for TSS content (8.57^o brix) of noni fruits. Among the sub plot, S_4 (50% FYM + 50% VC) recorded the highest TSS (10.18^o brix) content and this was followed by S_2 (100% VC) with TSS of 9.95^o brix. Whereas S_8 (no manures and no fertilizers) exhibited the lowest score for TSS (7.83 ^{o} brix) of noni fruits.

The highest TSS content of fruits (11.26^o brix) was recorded in the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with TSS of 10.74^o brix. The TSS content was found to be the lowest (7.21^o brix) in the treatment M_4S_8 (check basin method of irrigation + no

Table 2. Effect of different water regimes and organic manures on juice recovery (%) of noni fruits.

Treatments	M_1	M_2	M_3	M_4	Mean
S_1	26.02	27.84	27.55	24.22	26.41
S_2	26.11	29.03	29.24	24.80	27.30
S_3	25.42	26.93	26.71	23.82	25.72
S_4	26.50	34.32	31.03	24.89	29.19
S_5	25.67	27.14	27.32	24.16	26.07
S_6	25.88	28.75	28.52	24.51	26.92
S_7	26.24	28.22	28.34	24.66	26.87
S_8	22.73	22.86	23.06	21.09	22.44
Mean	25.57	28.14	27.72	24.02	26.36
	M	**S**	**M at S**	**S at M**	
SE(d)	0.144	0.189	0.381	0.377	
CD at 5%	0.458	0.386	0.842	0.773	

Table 3. Effect of different water regimes and organic manures on TSS (° brix) of noni fruits.

Treatments	M_1	M_2	M_3	M_4	Mean
S_1	9.55	10.23	10.30	8.70	9.70
S_2	9.71	10.53	10.64	8.90	9.95
S_3	9.42	9.92	9.88	8.59	9.45
S_4	9.74	11.26	10.74	8.96	10.18
S_5	9.49	10.16	10.07	8.63	9.59
S_6	9.63	10.48	10.42	8.76	9.82
S_7	9.59	10.34	10.37	8.83	9.78
S_8	7.96	8.13	8.02	7.21	7.83
Mean	9.39	10.13	10.06	8.57	9.54
	M	**S**	**M at S**	**S at M**	
SE(d)	0.051	0.069	0.138	0.137	
CD at 5%	0.162	0.140	0.303	0.280	

manures and no fertilizers).

Ascorbic acid

Among the irrigation regimes, M_2 (100% WRc through drip irrigation) recorded the highest ascorbic acid content (165.80 mg/100 g) and this was on par with M_3 (125% WRc through drip irrigation) with 164.80 mg/100 g of ascorbic acid (Table 4). Whereas the lowest ascorbic acid content (126.99 mg/100 g) was noticed from treatment comprising check basin method of irrigation (M_4).

Regarding the sub plots, application of 50% FYM + 50% VC (S_4) exhibited the superior scores for ascorbic acid content (165.93 mg/100 g) and this was followed by S_2 (100% VC) with 160.97 mg/100g. While the treatment S_8 (no manures and no fertilizers) showed very poor performance for ascorbic acid content with 119.76 mg/100 g.

Among the interactions, the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) registered the highest ascorbic acid content (197.82 mg/100 g) and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with ascorbic acid content of 191.35 mg/100 g. Whereas the ascorbic acid content was found to be the lowest (116.08 mg/100 g) in the treatment combination M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

Titrable acidity

Concerning the main plot, M_2 (100% WRc through drip irrigation) produced the fruits with the highest titrable acidity (0.352%) and this was on par with M_3 (125% WRc through drip irrigation) with titrable acidity of 0.350% (Table 5). The titrable acidity was found to be the lowest (0.292%) in M_4 (check basin method of irrigation).

Table 4. Effect of different water regimes and organic manures on ascorbic acid (mg/100 g) content of noni fruits.

Treatments	M_1	M_2	M_3	M_4	Mean
S_1	136.21	166.85	162.59	127.69	148.34
S_2	142.06	184.74	186.52	130.56	160.97
S_3	135.83	151.28	149.55	124.10	140.19
S_4	142.57	197.82	191.35	131.97	165.93
S_5	136.10	157.77	155.02	124.92	143.45
S_6	138.53	174.27	181.65	129.22	155.92
S_7	144.63	172.56	170.39	131.38	154.74
S_8	120.47	121.14	121.35	116.08	119.76
Mean	137.05	165.80	164.80	126.99	148.66
	M	**S**	**M at S**	**S at M**	
SE(d)	0.855	1.066	2.169	2.132	
CD at 5%	2.720	2.183	4.826	4.367	

Table 5. Effect of different water regimes and organic manures on titrable acidity (%) of noni fruits.

Treatments	M_1	M_2	M_3	M_4	Mean
S_1	0.320	0.356	0.353	0.292	0.330
S_2	0.328	0.371	0.375	0.302	0.344
S_3	0.318	0.343	0.340	0.285	0.322
S_4	0.330	0.392	0.383	0.310	0.354
S_5	0.319	0.351	0.347	0.287	0.326
S_6	0.325	0.364	0.368	0.296	0.338
S_7	0.334	0.362	0.361	0.306	0.341
S_8	0.270	0.274	0.276	0.256	0.269
Mean	0.318	0.352	0.350	0.292	0.328
	M	**S**	**M at S**	**S at M**	
SE(d)	0.002	0.002	0.005	0.005	
CD at 5%	0.006	0.005	0.011	0.010	

Regarding the manure treatments, application of 50% FYM + 50% VC (S_4) had resulted in the highest titrable acidity of 0.354%. While S_8 (no manures and no fertilizers) registered the least score for titrable acidity (0.269%).

Pertaining to interaction, the highest titrable acidity of 0.392% was recorded from the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) and this was on par with M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) which recorded titrable acidity of 0.383%. The treatment combination, M_4S_8 (check basin method of irrigation + no manures and no fertilizers) recorded the least score (0.256%) for titrable acidity of fruits.

Fruit firmness

Concerning the main plot, M_2 (100% WRc through drip irrigation) registered the highest fruit firmness (2.62 kg/cm^2) and this was on par with M_3 (125% WRc through drip irrigation) with 2.59 kg/cm^2 (Table 6). While the lowest fruit firmness (1.63 kg/cm^2) was recorded by M_4 (check basin method of irrigation).

Pertaining to the sub plot treatments, S_4 (50% FYM + 50% VC) produced the fruits with high firmness of 2.63 kg/cm^2 and this was followed by S_2 (100% VC) with 2.55 kg/cm^2. While the treatment S_8 (no manures and no fertilizers) recorded the lowest fruit firmness of 1.33 kg/cm^2.

Among the interactions, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the superior score for fruit firmness (3.26 kg/cm^2) and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with fruit firmness of 3.15 kg/cm^2. Fruit firmness was found to be the lowest (1.20 kg/cm^2) in the treatment combination M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

Table 6. Effect of different water regimes and organic manures on fruit firmness (kg/cm^2).

Treatments	M_1	M_2	M_3	M_4	Mean
S_1	2.14	2.80	2.71	1.71	2.34
S_2	2.26	3.03	3.10	1.80	2.55
S_3	1.97	2.43	2.37	1.55	2.08
S_4	2.29	3.26	3.15	1.83	2.63
S_5	2.06	2.52	2.48	1.58	2.16
S_6	2.20	2.84	2.92	1.73	2.42
S_7	2.08	2.67	2.59	1.65	2.25
S_8	1.32	1.42	1.37	1.20	1.33
Mean	2.04	2.62	2.59	1.63	2.22
	M	**S**	**M at S**	**S at M**	
SE(d)	0.013	0.016	0.033	0.033	
CD at 5%	0.040	0.034	0.073	0.067	

Table 7. Effect of different water regimes and organic manures on total carbohydrate content (mg/100 g) of noni fruits.

Treatments	M_1	M_2	M_3	M_4	Mean
S_1	543.27	562.78	563.29	530.68	550.01
S_2	549.48	575.44	577.32	533.86	559.03
S_3	540.38	557.08	556.37	529.15	545.75
S_4	553.61	584.39	581.26	537.25	564.13
S_5	541.26	560.72	557.84	529.84	547.42
S_6	545.44	571.52	569.74	533.15	554.96
S_7	552.84	567.20	567.81	536.49	556.09
S_8	509.21	512.69	512.10	503.64	509.41
Mean	541.94	561.48	560.72	529.26	548.35
	M	**S**	**M at S**	**S at M**	
SE(d)	1.461	1.958	3.943	3.915	
CD at 5%	4.649	4.010	8.691	8.020	

Total carbohydrate

Among the irrigation regimes, application of 100% WRc through drip irrigation (M_2) had resulted in the utmost total carbohydrate content (561.48 mg/100 g) while lower amount of total carbohydrate (529.26 mg/100 g) was found to be with check basin method of irrigation (M_4). Regarding the sub plots, application of 50% FYM + 50% VC (S_4) exhibited the superior scores for total carbohydrate content (564.13 mg/100 g) and this was followed by S_2 (100% VC) with 559.03 mg/100 g. While the treatment S_8 (no manures and no fertilizers) showed very poor performance for total carbohydrate content with 509.41 mg/100 g (Table 7). Among the interactions, the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) registered the highest total carbohydrate content of 584.39 mg/100 g and this was on par with M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with 581.26 mg/100 g. The total carbohydrate content was found to be the lowest (503.64 mg/100 g) in the treatment combination M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

Total phenol

Among the main plot treatments provision of 100% WRc through drip irrigation (M_2) was found to have profound influence on the total phenol content of noni fruits (Table 8). The highest total phenol content (316.92 mg/100 g) of fruits was observed from the treatment M_2 (100% WRc through drip irrigation) and this was on par with M_3 (125% WRc through drip irrigation) with total phenol content of 315.82 mg/100 g. The treatment M_4 (check basin method of irrigation) recorded the lowest total phenol content of229.38 mg/100 g.

Between the sub plots, application of 50% FYM + 50%

Table 8. Effect of different water regimes and organic manures on total phenol content (mg /100 g) of noni fruits.

Treatments	M_1	M_2	M_3	M_4	Mean
S_1	275.42	323.51	318.64	230.49	287.02
S_2	280.96	351.08	354.28	240.57	306.72
S_3	272.14	302.35	308.68	226.06	277.31
S_4	284.12	374.26	358.50	246.35	315.81
S_5	270.02	315.27	317.89	231.87	283.76
S_6	279.05	342.56	340.02	237.68	299.83
S_7	285.56	331.46	334.83	248.52	300.09
S_8	187.06	194.85	193.74	173.52	187.29
Mean	266.79	316.92	315.82	229.38	282.23
	M	**S**	**M at S**	**S at M**	
SE(d)	1.539	2.052	4.136	4.104	
CD at 5%	4.899	4.203	9.122	8.406	

VC (S_4) registered the highest scores for total phenol content (315.81 mg/100 g) and this was followed by S_2 (100% VC) with 306.72 mg/100 g of total phenol content, while the lowest total phenol content (187.29 mg/100 g) was recorded from the treatment S_8 (no manures and no fertilizers).

The experimental plots receiving 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) produced the fruits with high total phenol content (374.26 mg/100 g) and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with total phenol content of 358.50 mg/100g. While the lowest total phenol content (173.52 mg/100 g) was recorded from the treatment combination M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

Total carotenoid

Increased carotenoid content of fruits were registered in the treatment M_2 (100% WRc through drip irrigation) with 0.160 mg/100 g as compared to the treatment M_4 (check basin method of irrigation) with 0.128 mg/100 g (Table 9). In the sub plots, S_4 (50% FYM + 50% VC) exhibited the highest score of 0.161 mg/100g carotenoid content and the treatment S_8 (no manures and no fertilizers) with the lowest carotenoid content of 0.108 mg/100 g. Among the interactions, the treatment M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) showed the highest carotenoid content (0.177 mg/100 g) and decreased contents were seen in the treatment from M_4S_8 (check basin method of irrigation + no manures and no fertilizers) with 0.104 mg/100 g.

Protein content

Concerning the main plot, M_2 (100% WRc through drip irrigation) registered the highest protein content of 393.13 mg/100 g and this was on par with M_3 (125% WRc through drip irrigation) with 392.54 mg/100 g (Table 10). While the lowest protein content (364.03 mg/100 g) was recorded by M_4 (check basin method of irrigation). Application of 50% FYM + 50% VC (S_4) produced the fruits with higher protein content (394.29 mg/100 g) and this was followed by 100% VC (S_2) with protein content of 389.91 mg/100 g. The treatment comprising no manures and no fertilizers (S_8) registered the fruits with decreased protein content of 352.40 mg/100 g. Among the interaction, the highest protein content of 412.95 mg/100 g was recorded from the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) and this was on par with M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with protein content of 410.79 mg/100 g. The treatment combination, M_4S_8 (check basin method of irrigation + no manures and no fertilizers) recorded the least score (347.62 mg/100 g) for protein content of fruits.

Total flavonoids

The highest total flavonoid content of 119.52 mg/100 g was recorded by the treatment M_2 (100% WRc through drip irrigation) in main plot and the treatment M_4 (check basin method of irrigation) registered the lowest score of 103.76 mg/100 g (Table 11). Among the sub plot treatments application of 50% FYM + 50% VC (S_4) recorded the highest values for total flavonoid content (119.54 mg/100 g) which is on par with 100% VC (S_2) with 118.37 mg/100 g. While the treatment no manures and no fertilizers (S_8) recorded the lowest total flavonoid content of 95.69 mg/100 g. Interaction effects of the treatment M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) exhibited the highest total flavonoid content (128.53 mg/100 g) which is on par with M_3S_4

Table 9. Effect of different water regimes and organic manures on total carotenoid content (mg/100 g) of noni fruits.

Treatments	M_1	M_2	M_3	M_4	Mean
S_1	0.145	0.164	0.162	0.131	0.151
S_2	0.153	0.171	0.172	0.134	0.158
S_3	0.141	0.157	0.156	0.125	0.145
S_4	0.154	0.177	0.174	0.138	0.161
S_5	0.144	0.160	0.159	0.127	0.148
S_6	0.148	0.170	0.168	0.132	0.155
S_7	0.149	0.166	0.167	0.135	0.154
S_8	0.108	0.111	0.110	0.104	0.108
Mean	0.143	0.160	0.159	0.128	0.147
	M	**S**	**M at S**	**S at M**	
SE(d)	0.0004	0.0005	0.0011	0.0011	
CD at 5%	0.0013	0.0011	0.0024	0.0022	

Table 10. Effect of different water regimes and organic manures on protein (mg/100 g) content of noni fruits.

Treatments	M_1	M_2	M_3	M_4	Mean
S_1	374.65	389.55	391.20	364.62	380.01
S_2	381.24	406.38	404.79	367.24	389.91
S_3	373.29	388.73	386.98	362.68	377.92
S_4	384.26	412.95	410.79	369.14	394.29
S_5	375.29	391.56	394.24	364.44	381.38
S_6	378.66	402.53	399.75	366.75	386.92
S_7	381.63	397.53	398.26	369.76	386.80
S_8	351.88	355.80	354.29	347.62	352.40
Mean	375.11	393.13	392.54	364.03	381.20
	M	**S**	**M at S**	**Sat M**	
SE(d)	1.018	1.361	2.743	2.722	
CD at 5%	3.241	2.788	6.047	5.576	

Table 11. Effect of different water regimes and organic manures on total flavonoid (mg/100 g) content of noni fruits.

Treatments	M_1	M_2	M_3	M_4	Mean
S_1	111.06	119.78	119.31	104.58	113.68
S_2	114.70	126.13	126.68	105.95	118.37
S_3	111.43	118.25	117.56	102.63	112.47
S_4	115.65	128.53	127.24	106.74	119.54
S_5	112.39	118.69	119.02	105.20	113.83
S_6	114.04	124.48	123.80	105.52	116.96
S_7	115.23	122.69	123.17	107.28	117.09
S_8	95.74	97.63	97.21	92.18	95.69
Mean	111.28	119.52	119.25	103.76	113.45
	M	**S**	**M at S**	**S at M**	
SE(d)	0.608	0.813	1.638	1.625	
CD at 5%	1.936	1.665	3.611	3.330	

(125% WRc through drip irrigation + 50% FYM + 50% VC) with 127.24 mg/100 g. The lowest total flavonoid content of92.18 mg/100 g was expressed in the treatment M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

DISCUSSION

The increase in pulp and juice recovery percentage with the application of 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) might be due to optimum level of water and nutrient availability for fruit development. Increased soil moisture under drip irrigation might have led to effective absorption and utilization of nutrients resulting better source sink relationship which facilitates better fruit quality parameters. Reduced moisture availability in check basin method of irrigation resulting in water deficit might manifest many changes in plant anatomy such as decrease in size of cells and inter cellular spaces limiting cell division and elongation resulting in overall decrease in quality parameters as reported by Brantley and Warren (1960) and Prakash (2010).

The present study indicated that combined application 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) significantly improved the TSS content of fruits. Optimum moisture supply by drip irrigation might have enhanced the enzymatic activities thus resulting in translocation and accumulation of assimilates in fruits. This was line with the findings of Prakash (2010) in mango. Similarly, this might be due to the major role played by organic manures particularly FYM. FYM application facilitates the higher availability of micronutrients which would have played an important role in plant metabolism through their involvement in various enzymatic reactions. This was in line with the findings of Nayaki (2000) in tomato and sweet potato.

Application of organic manures particularly FYM and VC contain appreciable amount of micronutrients especially ferrous. It has been found that Fe is important as an essential component of the many respiratory enzymes like catalase, cytochrome A, B and C which are involved in the respiratory process in the cell system. Enhancement of respiration in a cell system or plant system will naturally result in the conversion of reserve food materials to soluble simple components which could be utilized for either growth or maintenance. This might be the cause for the increase in TSS content of noni fruits. The higher TSS achieved in this elite treatment may be attributed to accelerated mobilization of photosynthates from the leaves by auxins produced by *Azospirillum* (Tien et al., 1989).

Ascorbic acid content and titrable acidity was the highest in the treatment combination of 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4). The availability of adequate soil moisture with the required plant nutrients might have resulted in more uptake of plant by more profused rooting system in the plant which resulted in balanced nutrition and thereby increased the quality of fruits. These were conformity with findings of Kadam and Mayar (1992), Bafna et al. (1993) and Balasubramanian (2008).

Another possible reason for higher level of ascorbic acid content and titrable acidity might be due interaction effects of water regimes and organic manures which showed positive effect on ascorbic acid content (Jeeva, 1997). The increase in ascorbic acid content may be due to the optimum availability of N due to organic manures application (Randhawa and Bhail, 1976).

The increased level of ascorbic acid content may also be due to the action of micronutrients and growth hormones particularly gibberellins produced by the rhizosphere *Azospirillum,* phosphobacteria and *Azotobacter* and their activity of number of enzymes. Tien et al. (1989) also was of the opinion that gibberellins could either augment the biosynthesis of ascorbic acid or block the oxidation of synthesized ascorbic acid by ascorbic acid oxidase.

Fruit firmness was significantly higher in fruits harvested from plants that received 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) than those from check basin method of irrigation + no manures and no fertilizers (M_4S_8). This increased fruit firmness might be due to the optimum level of potassium availability through FYM and VC. The K related increase in fruit firmness was associated with increased ‘tissue pressure potential’. Tissue pressure potential was in turn, positively correlated with TSS and total carbohydrate content of fruits (Prakash, 2010). The increased total phenol content in 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) may due to presence of phenyl alanine in FYM which is the precursor for several phenolic substances would also have contributed to the increase in the total phenol content.

Marked increase in total carbohydrates in noni fruits with 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) may be due to more accumulation of photosynthates because of optimum N and K nutrients through organic manures and optimum moisture status through drip irrigation. It would have helped in accumulation of photosynthates through better availability of nutrients and water during cropping period ultimately favouring the increase in TSS and carbohydrate content in noni fruits. Similarly, the humic substances in FYM might have influenced the carbohydrate metabolism of plants and promoted the accumulation of more carbohydrates in the fruits. The earlier findings of Prakash (2010) are in validation with the present study.

In the present study, the protein content was significantly increased by combined application of 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4). FYM, rhizosphere *Azospirillum*, phosphobacteria and *Azotobacter* physiologically influence the activity of number of enzymes which leads to increased cell

metabolisms, enzymatic activity which in turn changes the biochemical composition of the produce (Okon, 1985). Rhizosphere *Azospirillum* and phosphobacteria due to the physiological influence on the activity of number of enzymes altered the proteins to a desired level. Hence, the protein content was increased. The enhanced absorption of nitrogen and its direct participation in protein synthesis might also be the reason as postulated by Subbiah and Ramanathan (1982).

Total flavonoid content was found to be the highest in M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) as against the lowest in M_4S_8 (check basin method of irrigation + no manures and no fertilizers). This may due to optimum soil moisture and nutrient status in the elite treatment.

In case of check basin method of irrigation, the interval between the two successive irrigations was higher due to which the available soil moisture content varied from the field capacity (at the time of irrigation) to stress condition (just before consecutive irrigation). These two extremes of moisture availability cause poor physiological activity of the crop, ultimately reflecting on the quality of the crop as already reported by many earlier workers *viz.*, Selvaraj (1997), Chakraborty et al*.* (1998) and Vijayselvaraj (2007). Similarly nutrient starvation prevailing in M_4S_8 (check basin method of irrigation + no manures and no fertilizers) may affect the physiological process which inturn affect the fruit quality parameters.

The treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) exhibited superior performance for all the quality parameters studied. Hence, it is recommended for production of best quality noni fruits with higher bioavailability of nutrients.

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