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Growth, flowering, fruit dimensions and post harvest parameters of *Morinda citrifolia* as influenced by irrigation regimes and organic manures

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An experiment was carried out in *Morinda citrifolia* through split plot design with irrigation regimes on main plot (four levels) and organic manures on sub plot (eight levels) with two replications. Among the treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% farmyard manure (FYM) + 50% vermicompost (VC) registered the highest plant height (148.74, 202.54 and 254.12 cm), number of primary branches (14.25, 26.32 and 33.74), number of secondary branches (21.89, 39.95 and 48.27), number of leaves (171.71, 429.52 and 875.31) and trunk girth (12.64, 22.58 and 28.07 cm) during vegetative, flowering and harvesting stages respectively. The same treatment takes very less days for first flowering (340.78) and 50% flowering (357.45). The treatment combination, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) exhibited the highest score for fruit length (11.20 cm), fruit circumference (18.02 cm), fruit volume (179.68 cc) and shelf life (4.21 days) and lowest score for physiological loss in weight (4.16, 7.72, 12.38, 17.56 and 23.49%).

Key words: *Morinda citrifolia,* drip irrigation, farmyard manure (FYM), vermicompost, growth, flowering, fruit length, fruit circumference, fruit volume, shelf life.

INTRODUCTION

Rise in population, inadequate supply of life saving essential drugs in certain parts of the world, prohibitive cost of treatments for even some common ailments, side effects of several allopathic drugs in current usage and development of resistance to these drugs for infectious disease have lead to increased emphasis on the use of herbal plant materials as source of medicines for the range of human ailments (Meena et al., 2009).

Morinda citrifolia popularly known as Indian Noni or Indian mulberry is an ever green small tree bearing flowers and fruits throughout the year. It belongs to the family Rubiaceae. It is grown in tropical regions of the world. It is one of the most significant sources of traditional medicines among Pacific islands. Noni has been used in folk remedies by Polynesians for over 2000 years and is reported to have a wide range of therapeutic effects including antibacterial, antiviral, antifungal, antitumor, analgesic, anti-inflammatory and immune enhancing effects (Mathivanan et al., 2005).

The roots, stems, bark, leaves, flowers and fruits of the noni plant are all involved in various combinations in almost 40 known and recorded herbal remedies. Noni fruit has excellent levels of carbohydrates and dietary fiber and is a good source of protein. Noni pulp is low in

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total fats. Noni is the biggest pharmaceutical unit in the universe because it has more than 160 nutraceuticals, several vitamins, minerals, micro and macro nutrients that help the body in various ways from cellular level to organ level (Rethinam and Sivaraman, 2007).

Noni fruit contains a number of enzymes and alkaloids that are believed to play a pivotal role in maintaining a good health. The fruit juice is in high demand in alternative medicine for different kinds of illnesses such as arthritis, diabetes, high blood pressure, muscle aches and pains, menstrual difficulties, headaches, heart disease, acquired immune deficiency syndrome (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 herbs 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.

Organic farming is the pioneer and safe farming system in harmony with nature. It is a system of agriculture that refrains from the use of synthetic chemicals, pesticides, etc., at every stage of growth and aimed to increase the productivity without disturbing natural resources. Organic manures act not only as a source of

nutrients and organic matter, but also enhance size, diversity and activity of the microbial population in soil and improves nutrient turnover and many other physical, chemical and biological parameters of soil (Gupta and Banoo, 2012). Organically grown products are in demand at present due to the awareness on health consciousness. This is true particularly in medicinal plants, wherein whole plant product is used in ayurvedic preparations (Maheswarappa et al., 1999).

The availability of irrigation water becomes dwindling day-by-day as such adoption of conventional methods of irrigation to crops leads to an acute scarcity of water and results in reduced production and productivity of crops. Surface irrigation is the most widespread irrigation technology in vogue, covering more than half of the area under irrigation worldwide. Generally, it is regarded as a wasteful technology as only 30 to 70% of the total water remains in the active root zone.

Therefore, it becomes imperative to go for alternate water saving methods and income for every drop of water through drip irrigation which provides continuous supply of required water in drops right at the root zone of the crop plant.

Drip irrigation is one of the latest innovative methods of irrigation, which enables slow and precise application of water for precise locations, avoiding wastage of water by deep percolation. By adopting drip irrigation, it is possible to increase the yield potential of crops by three times with the same quantity of water, by saving about 45 to 50% of irrigation water and increasing the productivity by about 40% (Behera et al., 2012). Drip irrigation can be used to improve the water use efficiency of horticultural crops by reducing evaporation and drainage losses by creating and maintaining soil moisture conditions that are favourable to crop growth.

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. Organically grown fruits and vegetables have been found to have long shelf-life with a capacity to withstand long distance transport.

Successful cultivation of noni in larger areas will help in commercialization of its products which is known for its nutritive and pharmaceutical value. This will boost up the socio economic status of the farmer and country as a whole. Studies on organic farming with drip irrigation in medicinal plants especially in noni is stingy, hence, the study was undertaken at Horticultural College and Research Institute, TNAU, Periyakulam, Tamil Nadu, India which is situated at 77°E longitude, 10°N latitude and at an altitude of 300 m above mean sea level.

MATERIALS AND METHODS

Statistical design was done by split plot design was followed, the factors were 2, replications were 2, spacing was 3.6 m × 3.6 m, and number of plants per replication was 5.

Treatment details

Main plot (Irrigation)

M_1, 75% WRc (computed water requirement through drip irrigation); M_2, 100% WRc (computed water requirement through drip irrigation); M_3, 125% WRc (computed water requirement through drip irrigation); M_4, check basin method of irrigation (5 cm depth).

Sub plot (Organic manures)

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% RD of NPK through inorganic fertilizers (60:30:30 g nitrogen:phosphorus:potassium (NPK) plant^{-1}); S_8, Control (no manures and no fertilizers).

All organic manures were applied on equivalent weight of recommended dose of nitrogen (60 g plant^{-1}) on N equivalent basis. The treatments S_1 to S_6 were applied in addition with *Azospirillum* (10 g plant^{-1}) + phosphobacteria (10 g plant^{-1}) + vesicular arbuscular mycorrhiza (VAM; 20 g plant^{-1}).

Computed water requirement

Computed water requirement of noni was calculated using the formula:

$$WRc = P_e \times K_p \times K_c \times A \times WP \text{ lit plant}^{-1}\text{day}^{-1}$$ (Allen et al., 1998).

where WRc = Computed water requirement (lit plant^{-1}day^{-1}), 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 noni tree (3.6 m × 3.6 m), and WP = Wetted percentage (40).

Observations

Growth parameters

Plant height: Plant height was measured from the base of the plant at ground level to tip of main stem and expressed in centimeters (cm).

Number of primary branches: The number of primary branches arising from the main stem of each plant was recorded and expressed in numbers.

Number of secondary branches: The number of secondary branches arising from the primary branch of each plant was recorded and expressed in numbers.

Number of leaves per plant: The total number of leaves of individual plant was counted and the mean was calculated and expressed as numbers per plant.

Trunk girth: Trunk girth was measured at base of the plant and expressed in centimeters (cm).

Flowering characters

Days taken for first flowering: The number of days taken for first flowering from planting was counted and expressed in days.

Days taken for 50% flowering: The number of days taken for flowering from 50% of the population in a treatment was recorded and expressed in days.

Fruit characters

Fruit length: The length of the fruit was measured from the stylar end to pedicel end by using a thread and scale and expressed in centimeters (cm).

Fruit circumference: It was measured at the broadest portion of the fruit using a thread and scale and expressed in centimeters (cm).

Fruit volume: It was calculated by water displacement method in ten fruits and the average was expressed in cubic centimeters (cc).

Post harvest parameters

Shelf life: The shelf life of the fruits under ambient condition was observed by visual observation and expressed in terms of number of days.

Physiological loss in weight (PLW): The initial weight of fresh fruit was recorded and subsequently the weight was taken on every day. The PLW was estimated as follows and expressed in percentage.

$$\text{PLW (\%)} = \frac{\text{Initial weight of the fruit (g) - Final weight of the fruit (g)}}{\text{Initial weight of the fruit (g)}} \times 100$$

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

Growth parameters

Plant height

Among the main plot treatments, the highest plant height of 115.86, 166.94 and 206.74 cm in vegetative, flowering and harvesting stages respectively (Table 1 and Figure 1) was observed in the treatment M_2 (100% WRc through drip irrigation), whereas the lowest plant height in vegetative (71.26 cm), flowering (107.17 cm) and harvesting (132.70 cm) stages was observed in M_4 (check basin method of irrigation).

With regards to the sub plot, the treatment S_4 (50% FYM + 50% VC) exhibited the greatest plant height in vegetative (116.68 cm), flowering (164.57 cm) and harvesting (207.48 cm) stages. While the treatment S_8 (no manure and no fertilizers) registered the lowest plant height with 55.44, 87.34 and 106.28 cm in vegetative, flowering and harvesting stages, respectively.

Among the interactions, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the tallest plants in vegetative (148.74 cm), flowering (202.54 cm) and harvesting (254.12 cm) stages of plant growth and this treatment combination was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) as the second one with 140.26, 192.91 and 239.43 cm plant height in vegetative, flowering and harvesting stages, respectively. Whereas the lowest height of plant (48.32, 76.74 and 93.22 cm) was observed in the treatment combination M_4S_8 (check basin method of irrigation + no manure and no fertilizers).

Number of primary branches

An increased number of primary branches per plant (10.73, 20.47 and 25.55) in vegetative, flowering and harvesting stages, respectively (Table 2) was observed in the treatment M_2 (100% WRc through drip irrigation), whereas comparatively a decreased number of primary branches per plant (6.60, 13.33 and 17.32) were noticed in the M_4 (check basin method of irrigation) at vegetative, flowering and harvesting stages respectively.

In the sub plot, the treatment S_4 (50% FYM + 50% VC)

Table 1. Effect of different water regimes and organic manures on plant height (cm).

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	91.54	120.37	117.12	73.58	100.65	137.32	173.62	172.38	108.27	147.90	173.63	213.28	209.39	133.50	182.45
S_2	96.42	134.47	137.61	76.47	111.24	142.29	184.51	187.28	116.18	157.57	181.70	230.56	234.24	141.47	196.99
S_3	85.55	102.19	105.84	67.44	90.26	133.22	157.25	156.52	101.56	137.14	164.58	196.72	193.47	125.04	169.95
S_4	97.38	148.74	140.26	80.33	116.68	144.74	202.54	192.91	118.09	164.57	189.77	254.12	239.43	146.60	207.48
S_5	87.49	109.68	112.16	71.07	95.10	136.05	167.44	163.67	104.83	143.00	165.17	205.09	201.32	131.13	175.68
S_6	94.73	127.23	131.07	74.36	106.85	140.53	180.08	182.36	111.41	153.60	178.82	223.62	226.43	137.75	191.66
S_7	100.29	124.36	123.41	78.50	106.64	151.20	178.42	176.19	120.26	156.52	187.18	220.13	216.66	152.91	194.22
S_8	55.41	59.81	58.22	48.32	55.44	87.46	91.63	93.51	76.74	87.34	107.62	110.43	113.86	93.22	106.28
Mean	88.60	115.86	115.71	71.26	97.86	134.10	166.94	165.60	107.17	143.45	168.56	206.74	204.35	132.70	178.09
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.5638	0.7218	1.4633	1.4435	-	0.7949	1.0529	2.1242	2.1058	-	0.9803	1.3092	2.6381	2.6183	-
CD at 5%	1.7943	1.4785	3.2438	2.9570		2.5299	2.1568	4.6886	4.3136		3.1197	2.6818	5.8172	5.3636	
CD at 1%	3.2935	1.9947	4.7126	3.9894		4.6439	2.9099	6.7862	5.8197		5.7266	3.6181	8.4121	7.2362	

CD: Certificate of deposit.

recorded greater scores for primary branches per plant in vegetative (10.67), flowering (20.63) and harvesting (25.77) stages, while the treatment S_8 (no manures and no fertilizers) registered the lowest primary branches (5.66, 10.66 and 13.89) during vegetative, flowering and harvesting stages, respectively.

Among the interactions, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) exhibited the highest number of primary branches per plant (14.25, 26.32 and 33.74) at all stages of crop growth. This was followed by the treatment combination M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with 12.56, 23.29 and 28.23 primary branches per plant in vegetative, flowering and harvesting stages respectively, whereas the lowest number of primary branches per plant in vegetative (4.34), flowering (8.96) and harvesting (12.14) stages was registered by the treatment combination comprising check basin method of irrigation + no manure and no fertilizers (M_4S_8).

Number of secondary branches

Application of 100% WRc through drip irrigation (M_2) recorded the highest number of secondary branches per plant in vegetative (18.14), flowering (34.15) and harvesting (41.75) stages (Table 3), while the treatment M_4 (check basin method of irrigation) recorded the lowest values for secondary branches per plant (12.35, 23.02 and 27.95).

Among the various manure treatments, application of 50% FYM + 50% VC (S_4) recorded the highest number of secondary branches per plant (18.09, 33.39 and 40.46) in vegetative, flowering and harvesting stages. The lowest number of secondary branches per plant of 9.96, 17.35 and 21.23 was noticed from the treatment S_8 (no manure and no fertilizers) in vegetative, flowering and harvesting stages respectively. Among the interaction, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the highest number of secondary branches per plant in vegetative (21.89), flowering (39.95) and harvesting (48.27) stages and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with 20.46, 37.68 and 45.82 branches in different stages of crop growth. Check basin method of irrigation + no manure and no fertilizers (M_4S_8) treatment combination exhibited the lowest secondary branches per plant in vegetative (9.15), flowering (16.34) and harvesting (20.16) stages.

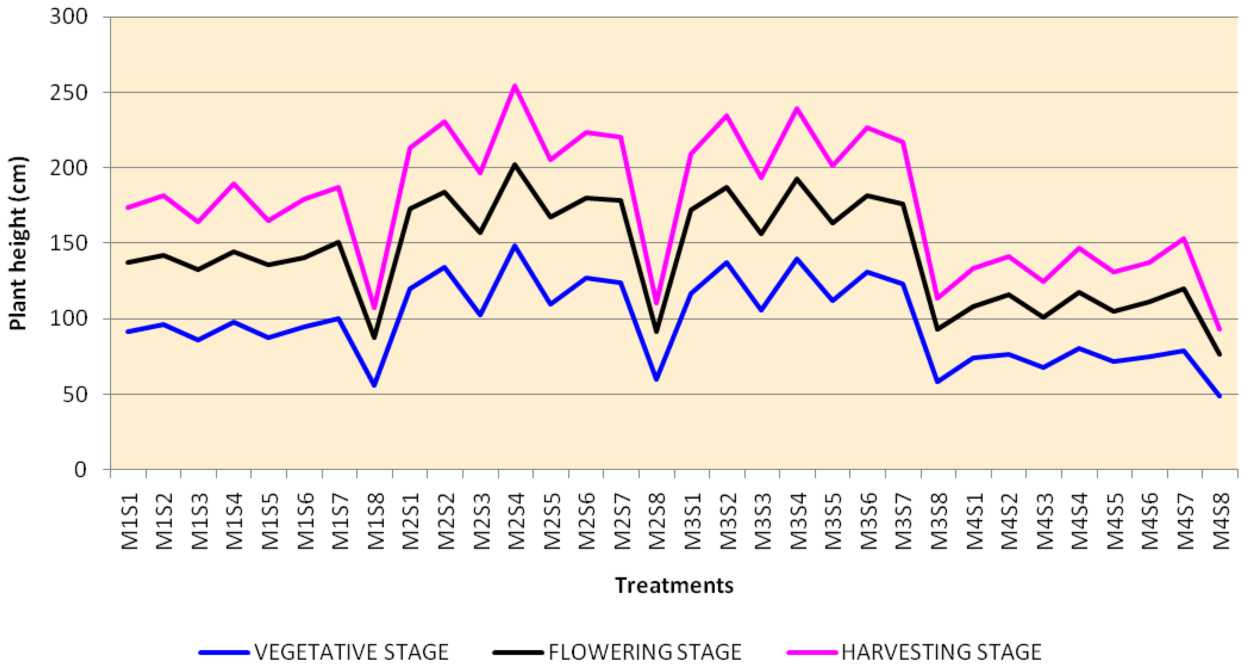

Figure 1. Effect of different water regimes and organic manures on plant height (cm).

Number of leaves

The treatment M_2 (100% WRc through drip irrigation) produced the highest number of leaves (138.77, 331.88 and 625.27) in vegetative, flowering and harvesting stages respectively (Table 4). Among the main plots, M_4 (check basin method of irrigation) exhibited the lowest number of leaves per plant (77.26, 155.46 and 318.89) in various stages of crop growth.

Regarding the different manure treatments, combined application of 50% FYM + 50% VC (S_4) registered more number of leaves in vegetative (135.95), flowering (326.11) and harvesting (635.78) stages, while S_8 (no manure and no fertilizers) recorded the lowest number of leaves of 59.09, 108.06 and 219.08 in vegetative, flowering and harvesting phases, respectively.

Among the interactions the treatment combination of M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) produced the highest number of leaves per plant (171.71, 429.52 and 875.31) in vegetative, flowering and harvesting stages respectively, whereas the number of leaves was found to be the lowest (48.21, 91.35 and 181.24) in the treatment combination M_4S_8 (check basin method of irrigation + no manure and no fertilizers) in all stages of crop growth.

Trunk girth

Among the main plot treatments, application of 100% WRc through drip irrigation (M_2) exhibited superior performance for trunk girth during vegetative (9.83 cm), flowering (17.70 cm) and harvesting (21.27 cm) phases (Table 5). The treatment M_4 (check basin method of irrigation) registered the lowest trunk girth (6.76, 12.21 and 13.80 cm) during different crop growth stages.

Among the manure treatments, application of 50% FYM + 50% VC (S_4) recorded the highest trunk girth (9.86, 17.86 and 21.46 cm) at three different stages respectively. The lowest trunk girth of 6.02, 10.02 and 10.98 cm was noticed from the treatment S_8 (no manure and no fertilizers) in vegetative, flowering and harvesting stages respectively.

Among the interaction, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the highest trunk girth in vegetative (12.64 cm), flowering (22.58 cm) and harvesting (28.07 cm) stages and this treatment combination was significantly differed from all other treatment combinations for trunk girth and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with girth of 11.18, 19.73 and 24.12 cm in different stages of crop growth. Check basin method of irrigation + no manure and no fertilizers (M_4S_8) treatment combination exhibited the lowest trunk girth in vegetative (5.12 cm), flowering (8.49 cm) and harvesting (9.27 cm) stages.

Flowering characters

Days taken for first flowering

Among the main plots, application of 100% WRc through

Table 2. Effect of different water regimes and organic manures on number of primary branches per plant.

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	8.33	10.63	10.32	6.81	9.02	17.05	21.10	20.83	13.37	18.09	21.57	25.68	25.92	17.69	22.72
S_2	8.54	12.08	12.27	7.04	9.98	17.89	22.38	22.84	14.32	19.36	22.82	27.88	27.14	18.61	24.11
S_3	7.96	9.43	9.21	6.59	8.30	16.11	19.17	18.71	12.29	16.57	20.52	24.11	23.85	16.68	21.29
S_4	8.77	14.25	12.56	7.11	10.67	17.81	26.32	23.29	15.09	20.63	22.37	33.74	28.23	18.75	25.77
S_5	8.12	10.14	10.03	6.72	8.75	17.16	20.26	20.51	13.09	17.76	21.18	25.12	24.97	17.34	22.15
S_6	8.26	11.83	11.74	6.95	9.70	17.45	21.63	21.52	14.02	18.66	21.96	26.75	26.68	18.22	23.40
S_7	9.03	11.32	11.41	7.23	9.75	18.14	21.34	21.41	15.53	19.11	22.94	26.07	26.31	19.12	23.61
S_8	5.97	6.18	6.13	4.34	5.66	10.95	11.53	11.18	8.96	10.66	14.02	15.02	14.37	12.14	13.89
Mean	8.12	10.73	10.46	6.60	8.98	16.57	20.47	20.04	13.33	17.60	20.92	25.55	24.68	17.32	22.12
	M	**S**	**M atS**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.0522	0.0656	0.1333	0.1312		0.0957	0.1294	0.2603	0.2588		0.1195	0.1620	0.3257	0.3239	
CD at 5%	0.1661	0.1344	0.2963	0.2687	-	0.3045	0.2650	0.5731	0.5301	-	0.3804	0.3318	0.71670	0.6635	-
CD at 1%	0.3048	0.1813	0.4313	0.3625		0.5590	0.3576	0.8276	0.7151		0.6983	0.4476	1.0352	0.8952	

CD: Critical Difference.

Table 3. Effect of different water regimes and organic manures on number of secondary branches per plant

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	15.78	19.12	18.84	12.63	16.59	30.16	36.20	35.93	23.80	31.52	36.52	44.31	44.02	28.74	38.40
S_2	16.23	19.85	20.12	12.97	17.29	30.87	36.92	37.21	24.18	32.30	37.26	45.02	45.34	29.32	39.24
S_3	15.14	17.29	17.12	12.20	15.44	29.52	34.37	34.19	23.25	30.33	35.65	42.46	42.30	28.32	37.18
S_4	16.80	21.89	20.46	13.21	18.09	31.48	39.95	37.68	24.45	33.39	38.10	48.27	45.82	29.63	40.46
S_5	15.52	17.52	17.43	12.37	15.71	29.87	34.65	34.50	23.42	30.61	36.07	42.74	42.53	28.59	37.48
S_6	16.17	19.70	19.61	12.78	17.07	30.58	36.73	36.62	24.04	31.99	37.15	44.84	44.72	29.17	38.97
S_7	16.89	19.27	19.40	13.48	17.26	31.56	36.33	36.48	24.70	32.27	38.22	44.41	44.53	29.67	39.21
S_8	9.90	10.45	10.35	9.15	9.96	17.21	18.03	17.82	16.34	17.35	21.24	21.92	21.59	20.16	21.23
Mean	15.30	18.14	17.92	12.35	15.93	28.91	34.15	33.80	23.02	29.97	35.03	41.75	41.36	27.95	36.52
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.0873	0.1164	0.2345	0.2327		0.1587	0.2204	0.4418	0.4407		0.1928	0.2687	0.5384	0.5374	
CD at 5%	0.2777	0.2384	0.5172	0.4767	-	0.5051	0.4514	0.9696	0.9028	-	0.6136	0.5505	1.1813	1.1009	-
CD at 1%	0.5098	0.3216	0.7481	0.6431		0.9272	0.6090	1.3964	1.2180		1.1263	0.7427	1.7006	1.4853	

CD: Critical Difference.

Table 4. Effect of different water regimes and organic manures on number of leaves per plant.

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	103.54	146.16	143.91	77.74	117.84	223.29	337.26	344.47	153.59	264.65	437.42	612.32	644.19	323.57	504.38
S_2	113.15	156.54	160.67	84.33	128.67	252.16	395.58	401.67	178.52	306.98	470.10	739.51	773.62	362.18	586.35
S_3	96.48	128.21	131.24	72.69	107.16	202.17	309.50	300.27	131.73	235.92	406.50	532.43	514.24	282.21	433.85
S_4	117.27	171.71	164.24	90.56	135.95	269.02	429.52	411.46	194.44	326.11	481.06	875.31	802.74	384.02	635.78
S_5	100.22	138.18	136.45	76.18	112.76	215.25	325.51	319.65	142.20	250.65	419.05	587.41	564.83	302.25	468.39
S_6	109.72	154.48	152.19	80.64	124.26	239.23	382.27	376.53	162.23	290.07	451.22	722.38	710.17	344.41	557.05
S_7	122.51	150.08	149.31	87.71	127.40	288.71	358.14	368.32	189.64	301.20	498.60	683.68	691.46	371.27	561.25
S_8	60.28	64.79	63.06	48.21	59.09	109.54	117.26	114.08	91.35	108.06	214.28	249.13	231.68	181.24	219.08
Mean	102.90	138.77	137.63	77.26	114.14	224.92	331.88	329.56	155.46	260.46	422.28	625.27	616.62	318.89	495.77
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.6370	0.8534	1.7189	1.7068		1.5090	1.9953	4.0262	3.9905		2.9488	3.7624	7.6315	7.5247	
CD at 5%	2.0273	1.7481	3.7888	3.4962		4.8022	4.0872	8.8889	8.1744		9.3847	7.7071	16.9250	15.4141	
CD at 1%	3.7213	2.3585	5.4772	4.7169		8.8150	5.5142	12.8679	11.0284		17.2266	10.3980	24.5983	20.7959	

CD: Critical Difference.

Table 5. Effect of different water regimes and organic manures on trunk girth (cm)

Treatment	Vegetative stage					Flowering stage					Harvesting stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	7.85	9.83	9.61	6.92	8.55	14.51	17.81	17.52	12.37	15.55	17.36	21.65	21.21	14.05	18.57
S_2	8.21	10.89	10.65	7.11	9.22	15.23	19.26	18.73	13.04	16.57	18.26	23.79	23.21	14.92	20.05
S_3	7.63	9.10	8.87	6.62	8.06	14.11	16.87	16.59	11.82	14.85	16.05	19.75	19.43	13.62	17.21
S_4	8.42	12.64	11.18	7.18	9.86	15.76	22.58	19.73	13.37	17.86	18.59	28.07	24.12	15.06	21.46
S_5	7.90	9.42	9.21	6.83	8.34	13.81	17.25	17.03	12.11	15.05	16.45	20.68	20.12	13.87	17.78
S_6	8.03	10.32	10.43	7.02	8.95	14.96	19.05	18.62	12.79	16.36	17.81	22.54	22.92	14.47	19.44
S_7	8.64	10.03	10.17	7.29	9.03	16.14	18.02	18.33	13.69	16.55	19.12	21.89	22.09	15.13	19.56
S_8	6.21	6.41	6.33	5.12	6.02	10.21	10.73	10.64	8.49	10.02	11.24	11.75	11.66	9.27	10.98
Mean	7.86	9.83	9.56	6.76	8.50	14.34	17.70	17.15	12.21	15.35	16.86	21.27	20.60	13.80	18.13
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.0481	0.0617	0.1250	0.1233		0.0841	0.1120	0.2257	0.2239		0.10052	0.13309	0.26851	0.26618	
CD at 5%	0.1532	0.1263	0.2771	0.2526	-	0.2675	0.2294	0.4979	0.4587	-	0.31992	0.27263	0.59271	0.54525	-
CD at 1%	0.2812	0.1704	0.4025	0.3408		0.4911	0.3094	0.7202	0.6189		0.58724	0.36781	0.85792	0.73562	

CD: Critical Difference.

Table 6. Effect of different water regimes and organic manures on days taken for first flowering.

Treatment	M_1	M_2	M_3	M_4	Mean
S_1	350.66	344.95	345.60	354.55	348.94
S_2	348.89	342.32	342.73	353.78	346.93
S_3	352.09	347.75	347.40	355.93	350.79
S_4	348.24	340.78	341.50	352.84	345.84
S_5	351.34	347.08	346.53	355.68	350.16
S_6	350.12	343.24	343.76	354.29	347.85
S_7	349.70	344.26	343.88	353.25	347.77
S_8	362.14	360.29	360.92	365.79	362.29
Mean	351.65	346.33	346.54	355.76	350.07
	M	**S**	**M at S**	**S at M**	
SE(d)	0.3711	0.4995	1.0054	0.9989	-
CD at 5%	1.1812	1.0231	2.2149	2.0462	
CD at 1%	2.1681	1.3803	3.2003	2.7606	

CD: Critical Difference.

drip irrigation (M_2) registered the early flowering with 346.33 days (Table 6). Delayed flowering was recorded in the check basin method of irrigation (M_4) with 355.76 days.

Pertaining to the sub plot, application of 50% FYM + 50% VC (S_4) registered the earlier flowering with 345.84 days, whereas delayed and late flowering was noticed in S_8 (no manure and no fertilizers) with 362.29 days.

The treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) recorded the earliest flowering with 340.78 days and this was on par with M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with 341.50 days. The first flowering was found to be comparatively very late (365.79 days) in the treatment combination comprising check basin method of irrigation + no manure and no fertilizers (M_4S_8).

Days taken for 50% flowering

The 50% flowering (Table 7) was found to be the earliest (364.09 days) in M_2 (100% WRc through drip irrigation) as against 375.36 days in M_4 (check basin method of irrigation).

Among the sub plot treatments, S_4 (50% FYM + 50% VC) exhibited the lowest number of days (363.51 days) and S_8 (no manure and no fertilizers) registered the longest period (383.89 days) for 50% flowering.

In the combined effect of treatments, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) found to be the earliest (357.45 days) for 50% flowering as compared to that of M_4S_8 (check basin method of irrigation + no manure and no fertilizers) with 387.90 days.

Fruit characters

Fruit length

Among the main plot treatments, M_2 (100% WRc through drip irrigation) documented the highest fruit length of 9.92 cm (Table 8 and Figure 2). The length of the fruit was found to be the lowest (8.21 cm) in the treatment comprising check basin method of irrigation (M_4).

Likewise in the sub plots, the treatment S_4 (50% FYM + 50% VC) registered the highest fruit length of 10.11 cm. Among the sub plot, the treatment S_8 (no manure and no fertilizers) showed the lowest fruit length (6.19 cm).

In the interaction, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) produced the highest fruit length 11.20 cm which is followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with fruit length of 10.87 cm. The treatment combination M_4S_8 (check basin method of irrigation + no manure and no fertilizers) exhibited the lowest fruit length of 5.85 cm.

Fruit circumference

Among the main plot treatments, M_2 (100% WRc through drip irrigation) recorded the highest fruit circumference of 16.35 cm. The fruit circumference was found to be the lowest in the check basin method of irrigation (M_4) with 14.25 cm (Table 9).

Pertaining to the manure treatments, the treatment S_4 (50% FYM + 50% VC) registered the highest values for fruit circumference (16.51 cm), while the treatment S_8 (no manure and no fertilizers) registered the lowest fruit

Table 7. Effect of different water regimes and organic manures on days taken for 50% flowering.

Treatment	M_1	M_2	M_3	M_4	Mean
S_1	369.05	362.50	363.09	373.90	367.14
S_2	367.13	359.43	359.94	372.93	364.86
S_3	370.41	365.24	364.89	375.60	369.04
S_4	366.32	357.45	358.52	371.75	363.51
S_5	369.70	364.52	363.88	375.02	368.28
S_6	368.46	360.49	360.95	373.61	365.88
S_7	368.02	361.58	361.18	372.18	365.74
S_8	383.85	381.54	382.26	387.90	383.89
Mean	370.37	364.09	364.34	375.36	368.54
	M	**S**	**M at S**	**S at M**	
SE(d)	0.3911	0.5257	1.0585	1.0515	-
CD at 5%	1.2447	1.0770	2.3322	2.1539	
CD at 1%	2.2848	1.4530	3.3702	2.9059	

CD: Critical Difference.

Table 8. Effect of different water regimes and organic manures on fruit length (cm).

Treatment	M_1	M_2	M_3	M_4	Mean
S_1	9.24	10.21	10.28	8.47	9.55
S_2	9.46	10.68	10.79	8.64	9.89
S_3	9.03	9.85	9.77	8.23	9.22
S_4	9.53	11.20	10.87	8.84	10.11
S_5	9.14	10.14	10.08	8.31	9.42
S_6	9.29	10.55	10.49	8.58	9.73
S_7	9.64	10.36	10.41	8.75	9.79
S_8	6.20	6.38	6.33	5.85	6.19
Mean	8.94	9.92	9.88	8.21	9.24
	M	**S**	**M at S**	**S at M**	
SE(d)	0.0239	0.0335	0.0671	0.0670	-
CD at 5%	0.0762	0.0686	0.1472	0.1373	
CD at 1%	0.1399	0.0926	0.2118	0.1852	

CD: Critical Difference.

circumference of 12.68 cm.

In the interactions, the combination of the treatment M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) recorded the highest scores for fruit circumference with 18.02 cm and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with fruit circumference of 17.44 cm, whereas the lowest fruit circumference of 12.19 cm was noticed in the M_4S_8 (check basin method of irrigation + no manure and no fertilizers).

Fruit volume

In the main plot, the treatment comprising 100% WRc through drip irrigation (M_2) exhibited the greater fruit volume of 149.45 cc (Table 10). The treatment M_4 (check basin method of irrigation) however exhibited lower score for fruit volume (104.23 cc).

Among the sub plot, S_4 (50% FYM + 50% VC) registered the higher fruit volume with 152.11 cc. The fruit volume was least (70.33 cc) in the treatment S_8 (no manure and no fertilizers).

In the interaction, the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) registered the highest fruit volume (179.68 cc) and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with fruit volume of 173.62 cc, whereas the lowest fruit volume (63.74 cc) was obtained from treatment combination M_4S_8 (check

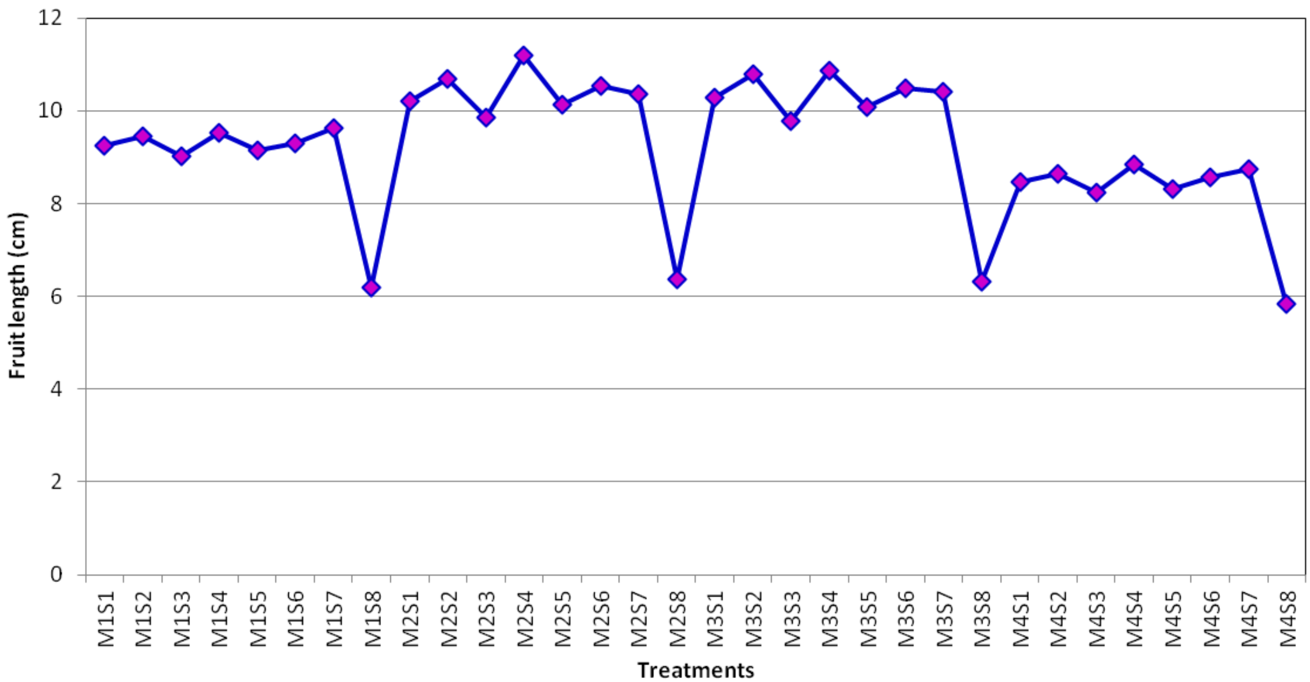

Figure 2. Effect of different water regimes and organic manures on fruit length (cm).

Table 9. Effect of different water regimes and organic manures on fruit circumference (cm).

Treatment	M_1	M_2	M_3	M_4	Mean
S_1	15.32	16.49	16.60	14.46	15.72
S_2	15.58	17.09	17.25	14.66	16.15
S_3	15.14	16.21	16.08	14.20	15.41
S_4	15.71	18.02	17.44	14.88	16.51
S_5	15.23	16.41	16.34	14.28	15.57
S_6	15.39	16.96	16.85	14.59	15.95
S_7	15.85	16.70	16.78	14.75	16.02
S_8	12.73	12.94	12.87	12.19	12.68
Mean	15.12	16.35	16.28	14.25	15.50
	M	**S**	**M at S**	**S at M**	
SE(d)	0.0411	0.0556	0.1119	0.1112	-
CD at 5%	0.1308	0.1139	0.2463	0.2279	
CD at 1%	0.2401	0.1537	0.3557	0.3074	

CD: Critical Difference.

basin method of irrigation + no manure and no fertilizers).

Post harvest parameters

Shelf life

Among the main plot treatments (Table 11 and Figure 3), the longest shelf life (3.80 days) was noticed in fruits under treatment M_2 (100% WRc through drip irrigation). The shortest shelf life (3.24 days) was observed in the treatment M_4 (check basin method of irrigation). Pertaining to the sub plot treatments, the longest shelf life (3.91 days) was noticed in fruits under treatment S_4 (50% FYM + 50% VC). The shortest shelf life (2.33 days) was observed in treatment S_8 (no manure and no fertilizers).

Table 10. Effect of different water regimes and organic manures on fruit volume (cc)

Treatment	M_1	M_2	M_3	M_4	Mean
S_1	127.75	153.95	155.62	107.86	136.30
S_2	133.40	167.29	170.18	112.36	145.81
S_3	122.39	145.72	142.29	101.24	127.91
S_4	136.52	179.68	173.62	118.62	152.11
S_5	125.28	151.86	150.42	103.59	132.79
S_6	129.58	164.58	161.89	110.85	141.73
S_7	139.52	157.62	159.44	115.57	143.04
S_8	69.63	74.89	73.06	63.74	70.33
Mean	123.01	149.45	148.32	104.23	131.25
	M	**S**	**M at S**	**S at M**	
SE(d)	0.3475	0.4839	0.9697	0.9678	
CD at 5%	1.1059	0.9912	2.1276	1.9824	-
CD at 1**%**	2.0301	1.3373	3.0632	2.6746	

CD: Critical Difference.

Table 11. Effect of different water regimes and organic manures on shelf life (days) of noni fruits

Treatment	M_1	M_2	M_3	M_4	Mean
S_1	3.58	3.98	4.02	3.34	3.73
S_2	3.71	4.12	4.14	3.46	3.86
S_3	3.52	3.80	3.78	3.27	3.59
S_4	3.75	4.21	4.17	3.50	3.91
S_5	3.54	3.87	3.84	3.30	3.64
S_6	3.66	4.09	4.07	3.42	3.81
S_7	3.60	3.91	3.94	3.37	3.71
S_8	2.32	2.38	2.36	2.24	2.33
Mean	3.46	3.80	3.79	3.24	3.57
	M	**S**	**M at S**	**S at M**	
SE(d)	0.0037	0.0052	0.0104	0.0104	
CD at 5%	0.0116	0.0106	0.0227	0.0213	
CD at 1%	0.0213	0.0143	0.0326	0.0287	

CD: Critical Difference.

In the combined effect of treatments, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) exhibited superior performance for shelf life with 4.21 days and this was followed by M_3S_4 (125% WRc through drip irrigation + 50% FYM + 50% VC) with 4.17 days. The shelf life of fruits was found to be the lowest (2.24 days) in the treatment combination comprising check basin method of irrigation + no manure and no fertilizers (M_4S_8).

Physiological loss in weight

Among the different main plot treatments implemented (Tables 12 and 13), the treatment M_2 (100% WRc through drip irrigation) showed the lowest PLW (5.01, 9.25, 14.94, 20.75 and 27.46%) during different days of storage. The PLW was found to be the highest in M_4 (check basin method of irrigation) with 5.83, 10.52, 16.76, 23.13 and 30.32% at one day, two, three, four and five days after storage respectively.

Regarding the sub plots, application of 50% FYM + 50% VC (S_4) recorded the lowest PLW of 4.59, 8.40, 13.39, 18.88 and 25.13%. The treatment comprising no manures and no fertilizers (S_8) registered the highest PLW of 9.01, 16.72, 27.94, 36.45 and 46.94%.

The treatment combination comprising 100% WRc

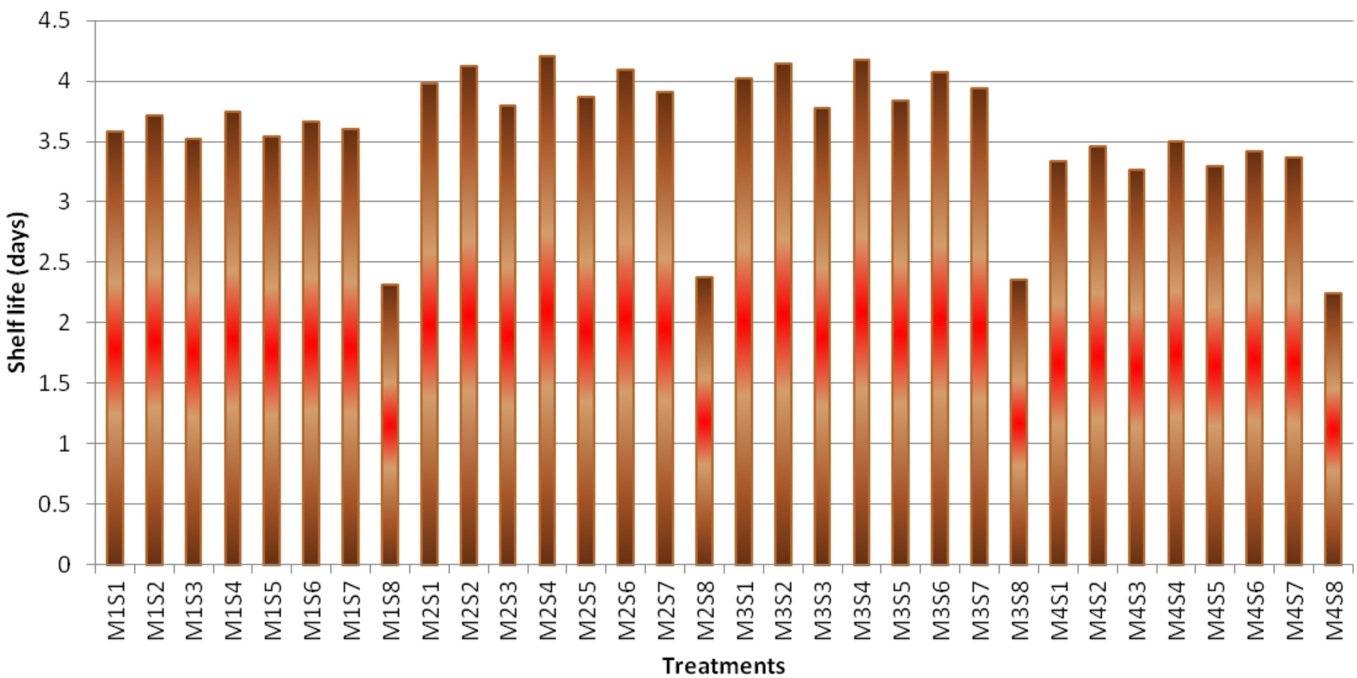

Figure 3. Effect of different water regimes and organic manures on shelf life (days) of noni fruits.

through drip irrigation + 50% FYM + 50% VC (M_2S_4) recorded the lowest PLW with 4.16, 7.72, 12.38, 17.56 and 23.49%. The PLW was found to be the highest (9.16, 16.92, 28.20, 36.77 and 47.35%) in the treatment combination comprising check basin method of irrigation + no manure and no fertilizers (M_4S_8).

DISCUSSION

Growth parameters

The plant height is the primary character which decides the vigour of the plant and inturn the dry matter production. It increased as the age of the crop progressed from vegetative to harvesting stage. The treatments involving 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) recorded the highest plant height at all the stages of crop.

Optimum moisture availability in 100% WRc through drip irrigation might have contributed to effective absorption and utilization of nutrients and better proliferation of roots resulting in better canopy growth. Better soil moisture condition may positively contribute for higher solubility and conductivity of nutrients which ultimately results into increased mass flow transport of nutrients. The frequent application of irrigation through drip at optimum level maintained most of the root zone with well aerated condition and at adequate soil moisture content that did not fluctuate between wet and dry extremes (Patil and Janawade, 1999).

Crops irrigated with 100% WRc irrigation regime performed better for all the growth parameters. This indicates that the crop's need was satisfied at 100% WRc.

FYM with narrow Carbon:Nitrogen (C:N) ratio might enhance the productivity of more humic acid and the humic substances along with phosphorus in chelated form (Padmapriya, 2004). The chelated phosphorus has been reported to be more soluble in water and its easy availability has helped in improving the height of the plant in noni. Besides, the presence of carbonic acid produced during the degradation process of FYM has favoured the mineralization of many needy nutrients, which are important for plant growth and development are made available to the crop plants. This might have increased the height of the plant in noni. This is in agreement with the previous work Padmanabhan (2003) in ashwagandha and Padmapriya (2004) in turmeric.

Similarly, addition of vermicompost would have improved the physical and chemical properties of the soil, such as they would have provided more nitrogen and phosphorus in the soil (Baby, 2012).

The increase in the plant height by FYM and vermicompost application might also be due to the improvement in soil physical conditions, namely, increased water holding capacity, reduction in bulk density, improved particle density, pore space, texture and soil available nutrient status and organic matter content which favourably interfered with the root growth and development, indirectly influenced the increased plant height. The results of the present study were in

Table 12. Effect of different water regimes and organic manures on physiological loss in weight (per cent) of noni fruits at one day, two days and three days after storage.

Treatment	One day after storage					Two days after storage					Three days after storage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	5.03	4.48	4.43	5.42	4.84	9.12	8.23	8.16	9.71	8.81	14.43	13.17	13.06	15.26	13.98
S_2	4.84	4.30	4.27	5.23	4.66	8.81	7.96	7.91	9.41	8.52	14.02	12.77	12.69	14.85	13.58
S_3	5.12	4.70	4.74	5.53	5.02	9.25	8.58	8.65	9.89	9.09	14.61	13.67	13.76	15.56	14.40
S_4	4.79	4.16	4.23	5.16	4.59	8.73	7.72	7.84	9.32	8.40	13.88	12.38	12.56	14.72	13.39
S_5	5.09	4.63	4.65	5.48	4.96	9.20	8.47	8.50	9.82	9.00	14.53	13.51	13.56	15.41	14.25
S_6	4.91	4.34	4.37	5.29	4.73	8.93	8.02	8.07	9.50	8.63	14.18	12.87	12.94	14.97	13.74
S_7	4.99	4.59	4.55	5.37	4.88	9.04	8.40	8.34	9.62	8.85	14.32	13.42	13.31	15.13	14.05
S_8	9.02	8.91	8.95	9.16	9.01	16.72	16.58	16.64	16.92	16.72	27.95	27.75	27.84	28.20	27.94
Mean	5.47	5.01	5.02	5.83	5.34	9.98	9.25	9.26	10.52	9.75	15.99	14.94	14.97	16.76	15.67
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.0064	0.0078	0.0159	0.0155	-	0.0118	0.0142	0.0290	0.0284	-	0.0192	0.0229	0.0470	0.0458	-
CD at 5%	0.0203	0.0159	0.0354	0.0318		0.0374	0.0291	0.0649	0.0582		0.0611	0.0469	0.1051	0.0939	
CD at 1%	0.0372	0.0215	0.0517	0.0429		0.0686	0.0392	0.0949	0.0785		0.1121	0.0633	0.1539	0.1266	

CD: Critical Difference

conformity with the earlier findings of Padmanabhan (2003) in ashwagandha and Umesha et al. (2011) in *Solanum nigrum.*

Lesser plant height in check basin method of irrigation + no manure and no fertilizers (M_4S_8) might be due to more moisture stress on plant and insufficient supply of essential nutrients during growth period. Reduced irrigation level in check basin method of irrigation cause 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 plant growth (May and Milthrope, 1962). In case of check basin method of irrigation, highly fluctuating moisture regimes resulted in stress to the crop and due to the excess irrigation, nutrients might have been leached away from the root zone as enlightened by Paul et al. (1996).

More number of primary and secondary branches were produced in the treatment combinations with 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4).

The enhanced growth under drip might be due to better turgidity of the cells, leading to cell enlargement and better cell wall development. Such increments may be due to the increasing water supply which improves root function, consequently enhance nutrient uptake and metabolic processes (Andria and Morelli, 2002). Thus, higher water uptake through drip irrigation ultimately resulted in higher plant growth.

Adequate availability and supply of nutrients and water in proportion ultimately resulted in increased production of plant growth hormones which could have resulted in more number of lateral production. The present findings are in consonance with previous observations of Padmanabhan (2003), Umesha et al. (2011) and Baby (2012).

Leaf is considered as an important functional unit of plant which contributes to the formation of assimilates. Number of leaves per plant plays an impressive role in the photosynthetic efficiency of the plant. A crop should produce sufficient number of leaves to harness light energy and synthesize adequate photoassimilates for biomass production. In the present study, the number of leaves produced from vegetative stage to harvesting stage revealed that 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) helped in maintaining a higher number of leafs throughout the cropping period.

This might be due to direct addition and slow release of nutrients through vermicompost (Bhardwaj and Omanwar, 1994) and FYM, thus enriching available nutrient pool of the soil which resulted in more number of leaves per plant. Higher number of leaves per plant might be also due to increased number of branches per plant.

Table 13. Effect of different water regimes and organic manures on physiological loss in weight (per cent) of noni fruits at four days and five days after storage

Treatment	Four days after storage					Five days after storage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	20.21	18.60	18.47	21.38	19.67	26.73	24.81	24.64	28.11	26.07
S_2	19.71	18.10	17.98	20.80	19.15	26.15	24.18	24.03	27.44	25.45
S_3	20.47	19.27	19.39	21.73	20.22	27.06	25.62	25.78	28.51	26.74
S_4	19.54	17.56	17.80	20.63	18.88	25.96	23.49	23.82	27.25	25.13
S_5	20.34	19.06	19.14	21.55	20.02	26.88	25.36	25.47	28.30	26.50
S_6	19.89	18.22	18.32	20.98	19.35	26.35	24.33	24.46	27.65	25.70
S_7	20.07	18.93	18.79	21.22	19.75	26.57	25.21	25.04	27.93	26.19
S_8	36.46	36.23	36.33	36.77	36.45	46.95	46.67	46.79	47.35	46.94
Mean	22.09	20.75	20.78	23.13	21.69	29.08	27.46	27.50	30.32	28.59
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SE(d)	0.0260	0.0315	0.0644	0.0629	-	0.0341	0.0414	0.0846	0.0827	-
CD at 5%	0.0829	0.0645	0.1438	0.1289		0.1086	0.0847	0.1889	0.1695	
CD at 1%	0.1522	0.0870	0.2103	0.1739		0.1994	0.1143	0.2761	0.2286	

CD: Critical Difference

The effect of vermicompost on plant growth could be attributed to presence of plant growth regulators and humic acid in vermicompost, which are produced by increased activity of beneficial microbes (Arancon and Edwards, 2005).

This may be also be attributed from the fact that FYM possesses optimum CN ratio, which on decomposition readily releases nitrogen in the easy available form of nutrient ions such as ammonium and nitrate. This increase in the nitrogen level of soil might have resulted in the production of more number of leaves per plant, since nitrogen is the chief constituent of amino acids and coenzymes of biological importance would have helped for better performance of metabolic activities that could have ultimately resulted in increased leaf number (Padmapriya, 2004).

Generally, organic manures improved the nutrient status of soil due to slow release of nutrients thereby preventing the wastage. Such manures increase the humus content in soil. Apart from this, addition of organic manures improves physical condition of soil by reducing bulk density and increase the cation exchange capacity of soil. High water holding capacity of soil along with enhanced microbial activity helped in better nutrient uptake by the plants. This might probably lead to increased carbon content in the humus rich soil, which has favoured the production of more number of leaves. This is in concurrence with earlier findings of Maheswarappa et al. (1999) in galangal.

The treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the highest trunk during different growth stages. The favourable moisture throughout the crop growth period through drip irrigation might have stimulated the physiological process of cell elongation and cell division which might have contributed to elongation of the stem on both directions. The increase in girth could also be attributed to the increase in uptake of nutrients. This increase in girth might be due to the increased cell wall plasticity ascribed to the stimulatory action of the nutrients and amino acids.

Flowering characters

Number of days taken for first flowering and 50% flowering was found to be in the lowest in the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4). Optimum water and nitrogen availability in the rhizosphere might have facilitated better uptake of nitrogen, the chief constituent of amino acid and coenzymes that are of biological importance. Optimum N uptake might have reduced the C:N ratio and thereby inducing flowers at earlier days. This may also be due to the higher net assimilation rate on account of better growth leading to the production of endogenous metabolites earlier in optimum level enabling early flower bud initiation and thereby early flowering. The lesser availability of N might be the reason for delayed flowering in check basin method of irrigation + no manure and no fertilizers (M_4S_8).

Further, this can be explained to the better source sink relationship in the treatments M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) which recorded the more leaf production, inturn more photosynthetic activity, translocating the carbohydrate efficiently to the developing sinks and such a view was also shared by Shakila and Manivannan (2001) and Vanilarasu (2011).

The earliness in flowering was attributed to the simultaneous transport of growth substances like cytokinin to the auxillary bud that breaks the apical dominance. Similar to the results of the present study, Vidhya (2004) also reported that improved vegetative growth due to high photosynthetic rate and high CO_2 fixation in the drip irrigated and organic manure treated plants enable them to enter the reproductive phase early.

In the present investigation, the treatment M_4S_8 (check basin method of irrigation + no manure and no fertilizers) had taken the longest duration for first flowering and 50% flowering. The poor plant height, trunk girth and leaf production recorded in the treatment M_4S_8 (check basin method of irrigation + no manure and no fertilizers) suggests that the water and nutrient demand was not met adequately and thus resulted in extended duration of crop cycle.

Fruit characters

The treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) resulted in the highest fruit length, fruit circumference and fruit volume.

Drip irrigation at optimum level provides a consistent moisture regime in the soil due to which root remains active throughout the season resulting in optimum uptake of water and nutrients. This facilitates proper translocation of food materials which accelerates the fruit growth and development in noni. The superior fruit characters under drip irrigation might be ascribed to better water utilization, minimum losses of water through percolation and evaporation and excellent soil-water-air relationship with higher oxygen concentration in the root zone and optimum uptake of nutrients. These results are in agreement with the findings of Bafna et al. (1993) and Prakash (2010).

This could be also due to the slow release of nutrients in synchrony with improved physical properties of soil resulting in optimum uptake of nutrients, which might have facilitated improvement in fruit characters. In addition to this, FYM has favoured the supply of micronutrients through its own decomposition, besides acting as an additional source of ammoniacal nitrogen ultimately resulting in increased fruit characters. FYM improved soil physical structure and texture, decreased the bulk density and increased moisture retention. All these comprehensive changes paved the way for greater fruit dimensions. Further, the reduced loss of nitrogen by ammonia volatilization and narrower C:N ratio might have also contributed to the better performance of crop supplied with FYM (Kirchmann and Witter, 1992).

Moreover addition of biofertilizers produces organic acids, namely, malic and succinic acids which convert insoluble soil phosphates to more soluble compounds thereby increasing the availability of nutrients. This increased nutrient availability could have resulted in higher accumulation of carbohydrates in sink thereby exerting a remarkable increase in fruit dimensions.

The increased fruit characters with organic nutrient application might have first improved the internal nutritive condition of plant leading to increased growth and vigour associated with photosynthesis and finally translocation of assimilates into the fruits (Vanilarasu, 2011).

Yet another possibility may be that humic substances present in FYM and vermicompost are capable of chelating metal ions such as Fe, Zn, etc., and retained in soil as exchangeable form. This form of nutrients is made easily available for plant growth. This might have attributed to increase the fruit characters.

The reduced fruit characters under M_4S_8 (check basin method of irrigation + no manure and no fertilizers) was due to moisture stress and nutrient deficiency which was affecting the photosynthetic efficiency of the plants. The reduction in the fruit size might be due to the reduction in the supply of assimilates to developing sink due to exhausting by excess respiration. This is line with the finding of Balasubramanian (2008) in tomato.

Post harvest parameters

Shelf life of noni is an important parameter and influenced directly by the pre harvest nutritional status of the fruits. In the current research, the influence of nutrients derived from organic sources had a positive effect on the post harvest characters of noni. The treatment M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the highest shelf life and the lowest physiological loss in weight. While M_4S_8 (check basin method of irrigation + no manure and no fertilizers) recorded the highest PLW with the lowest shelf life.

This can be attributed to the phenomenon that the altered physiology and biochemistry of the fruits as influenced by organic sources of nutrients might have led to the reduced respiration and evapotranspiration which in turn resulted in low PLW and the highest shelf life. This result lends support to the findings of Vanilarasu (2011) in banana.

Yet another possible reason for the improvement in storage behavior of noni harvested from crop subjected to 100% WRc through drip irrigation + 50% FYM + 50% VC might be optimum and continuous uptake of potassium nutrient from organics throughout the crop growth period. Optimum level of K helps in greater translocation of metabolites to storage organs and enhances thickening of cell wall of fruits. Thus efficient metabolism and better source sink relationship contributes on improved storage life in noni fruits. These results were in accordance with Madan and Sandhu (1983). Potash nutrition increase thickness of cell wall and helps in getting healthy fruits. Further, the strong skin of fruits guards them against decay and reduced rate of respiration during storage.

The treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) exhibited superior performance for all the growth characters, flowering attributes, fruit dimensions and post harvest parameters. Hence, it is recommended for production of noni with better fruit dimensions and shelf life.

REFERENCES

Allen RG, Pereira LS, Raes D, Smith M (1998). Crop evapotranspiration: Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No. 56, FAO, Rome. pp. 1-174.

Andria RD, Morelli G (2002). Irrigation regimes effects yield and oil quality of olive trees. Acta Hort. 586:273-276.

Arancon NQ, Edwards CA (2005). Effects of vermicomposts on plant growth. In: Proceedings of international symposium on vermi technologies for developing countries held at Los Banos, Philippines. pp. 1-25.

Baby PT (2012). Influence of ultra high density planting and organics in enhancing leaf production and protein content in annual moringa (*Moringa oleifera* Lam.) cv. PKM-1. MSc Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Bafna AM, Daftardar SY, Khade KK, Patel PV, Dhotre RS (1993). Utilization of nitrogen and water by tomato under drip irrigation system. J. Water Manage. 1:1-5.

Balasubramanian P (2008). Comparative analysis of growth, physiology, nutritional and production changes of tomato (*Lycopersicum esculentum* Mill.) under drip, fertigation and conventional systems. PhD Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Behera MS, Mahapatra PK, Verma OP, Singandhupe RB, Kumar A (2012). Drip fertigation impact on yield and alkaloid content of *Withania somnifera* (L.) Dunal. Med. Plants. 4(3):133-137.

Bhardwaj V, Omanwar PK (1994). Long term effect of continuous rotational cropping and fertilization on crop yields and soil properties. II. Effect of EC, pH, organic matter and available nutrient on soil. J. Indian Soc. Soil Sci. 42(3):387-392.

Kirchmann H, Witter E (1992). Composition of fresh, aerobic and anaerobic farm animal dungs. Bioresour. Technol. 40:137-142.

Madan PS, Sandhu S (1983). Studies on the storage behavior of white onion (*Allium cepa* L) variety as influenced by levels of N, P and K. Haryana Agric. Univ. J. Res.13(3):433-438.

Maheswarappa HP, Nanjappa HV, Hedge MR (1999). Influence of organic manures on yield of arrow root, soil physico-chemical and biological properties when grown as intercrop in coconut garden. Ann. Agric. Res. 20(3):318-323.

Mathivanan N, Surendiran G, Srinivasan K, Sagadevan E, Malarvizhi K (2005). Review on the current scenario of Noni research: Taxonomy, distribution, chemistry, medicinal and therapeutic values of *Morinda citrifolia.* Int. J. Noni Res. 1(1):1-16.

May LH, Milthrope FZ (1962). Drought resistance of crop plants. Fld. Crop Abst. 23: 171.

Meena AK, Bansal P, Kumar S (2009). Plants herbal wealth as a potential source of ayurvedic drugs**.** Asian J. Tradit. Med. 4(4):152-170.

Padmanabhan K (2003). Effect of organic manures on growth, root yield and alkaloid content of ashwagandha (*Withania somnifera* (L.) Dunal) 'Jawahar'. MSc Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Padmapriya S (2004). Studies on effect of shade, inorganic, organic and bio fertilizers on growth, yield and quality of turmeric (*Curcuma longa* L.) genotype CL 147. PhD Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Panse VG, Sukhatme PV (1985). Statistical methods for agricultural workers, Indian Council of Agricultural Research, New Delhi.

Patil VS, Janawade AD (1999). Soil-water-plant-atmosphere relationships. In: Proceedings of seminar on advances in micro irrigation and fertigation held at Dharwad, Karnataka. pp. 19-32.

Paul J, Joseph V, Kabeer TA (1996). Fertilizer irrigation - An overview. In: Proceedings of All India seminar on modern irrigation techniques held at Bangalore. pp. 191-195.

Prakash K (2010). Studies on influence of drip irrigation regimes and fertigation levels on mango var. Alphonso under ultra high density planting. MSc Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Rethinam P, Sivaraman K (2007). Noni (*Morinda citrifolia* L) the miracle fruit - A holistic review. Int. J. Noni Res. 2(1-2):4-37.

Shakila A, Manivannan K (2001). Response of *in vitro* raised banana *cv.* Robusta to different levels of N and K application. South Indian Hort. 49:362-364.

Umesha K, Soumya SP, Smitha GR, Sreeramu BS (2011). Influence of organic manures on growth, yield and quality of makoi (*Solanum nigrum* L.). Indian J. Hort. 68(2):235-239.

Vanilarasu K (2011). Standardization of organic nutrient schedule in banana cv. Grand Naine. MSc Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Vidhya D (2004). Studies on the effect of biofertilizers on banana cv. Robusta (AAA) at varying doses of inorganic fertilizers. MSc Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Wang MY, West B, Jensen CJ, Nowicki D, Su C, Palu AK, Anderson G (2002). *Morinda citrifolia* (Noni): a literature review and recent advances in noni research*.* Acta Pharmacol. Sin. 23:1127–1141.