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Soil and leaf nutrient status of noni (*Morinda citrifolia* L.) as influenced by drip irrigation and manurial treatments

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An investigation was carried out at Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam to find out the effect of various irrigation regimes and manurial treatments on soil and leaf nutrient status of noni (*Morinda citrifolia* L.). The experiment was carried out in split plot design with irrigation regimes on main plot and manurial treatments on sub plot. Among the treatment combination, M_2S_7 (100% WRc through drip irrigation + 100% recommended dose of NPK through inorganic fertilizers) showed the highest soil available nitrogen, phosphorus and potassium content. The same treatment combination recorded the increased leaf nitrogen, phosphorus and potassium content during vegetative, flowering and harvesting stages.

Key words: *Morinda citrifolia* L., drip irrigation, check basin method of irrigation, farmyard manure, vermicompost, coir pith compost, inorganic fertilizers, soil nutrient status, leaf nutrient status.

INTRODUCTION

Morinda citrifolia L. 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. Recently, it has been regaining popularity as an herbal treatment and is beginning to show resurgence as a cultivated plant. 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. Therefore, it becomes imperative to go for alternate water saving methods and income for every drop of water through trickle irrigation which provides continuous supply of required quantity of water in drops right at the root zone of the plant. In the cultivation of modern crop cultivars and appropriate management strategies, use of recent day chemical fertilizers have contributed up to 50%, a raise in food grain output (Braun and Roy, 1983). Despite the key role played by these fertilizers, a total dependence on them in achieving a contemplated productivity goal is not fully justified. Furthermore, an unabated up rise in the use of chemical fertilizers can inflict irreparable damage to land and the prevailing environment (Katyal, 1989). Measurable decrease in fertilizer consumption without compromising the yield and quality of any crop can also be made practically possible through organic inputs.

Continuous and unscrupulous use of chemical

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Table 1. Initial soil chemical and physico-chemical characteristics of the experimental field.

Properties	Details
Chemical properties	
Available nitrogen	173 kg ha^{-1}
Available phosphorus	24 kg ha^{-1}
Available potassium	340 kg ha^{-1}
Physico-chemical properties	
EC	0.32 dSm^{-1}
pH	7.93

Table 2. Nutrient content of organic manures.

Organic manure	Nutrient content (%)		
	N	P	K
FYM	0.75	0.37	0.71
Vermicompost	1.67	1.51	0.80
Coir pith compost	1.06	0.87	1.20

fertilizers, pesticides and fungicides without the incorporation of organic manure cause environmental degradation especially, in the soil thereby affecting its fertility on long term basis. For effectively 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 best recommendation. Large scale cultivation under organic conditions is gaining momentum to produce toxic free medicinal and herbal plant products (Padmanabhan, 2003). Organically grown herbal materials are more preferred in the herbal preparations since they are residue free and more effective. A judicious and continuous use of one or more organic sources like animal manures, green manures, oil cakes, crop residues and biofertilizers such as *Azospirillum*, phosphobacteria, VAM etc., could improve the soil fertility levels on a long term basis. Plant nutrient availability in the soil is very critical for exploiting higher production.

The nutrients, applied at any stage of crop growth, should properly reflect in terms of available nutrient in soil so that the plants could absorb these nutrients efficiently without any hindrance. Hence, the study was undertaken to find out the effect of different irrigation regimes and manurial treatments on soil and leaf nutrient status of noni.

MATERIALS AND METHODS

This study was conducted 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. The nature of soil of the experimental plot is sandy loam. The details of the initial soil chemical and physico-chemical characteristics of the experimental field were furnished in Table 1. The methods used were as follows:

a) Statistical design: Split plot design.
b) Factors: 2
c) Replications: 2
d) Spacing: 3.6 × 3.6 m
e) Number of plants per replication: 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% recommended dose (RD) of NPK through inorganic fertilizers (60:30:30 g 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 are applied in addition with *Azospirillum* (10 g $plant^{-1}$) + phosphobacteria (10 g $plant^{-1}$) + VAM (20 g $plant^{-1}$). Nutrient content of organic manures were given in Table 2. In the treatment S_7, nitrogen is applied in the form of urea, phosphorus in the form of super phosphate and potassium in the form of murate of potash.

Computed water requirement

Computed water requirement of noni was calculated by using the following formula:

$$WRc = CPE \times K_p \times K_c \times A \times Wp \text{ lit plant}^{-1}$$

Where WRc is Computed water requirement (lit $plant^{-1}$), CPE is cumulative pan evaporation for two days (mm), K_p is pan co-efficient (0.75), K_c is crop factor (0.90 for vegetative stage, 0.95 for flowering and harvesting stage) (Allen et al., 1998), A is area occupied by the noni tree (3.6 × 3.6 m), Wp is wetting percentage (40).

The quantity of water applied during the study period (June 2011 to March 2013) is enclosed in Table 3.

Observations

Soil nutrient analysis

Soil sampling: A ‘V’ shape cut was made to a depth of 15 cm at each sampling spot. About 1.5 cm thick slices of soil were removed

Table 3. Total water used during the study period.

Treatment	Water applied (mm)	Effective rainfall (mm)	Total water used (mm)
M_1S_1	619.85	400.5	1020.35
M_1S_2	619.85	400.5	1020.35
M_1S_3	619.85	400.5	1020.35
M_1S_4	619.85	400.5	1020.35
M_1S_5	619.85	400.5	1020.35
M_1S_6	619.85	400.5	1020.35
M_1S_7	619.85	400.5	1020.35
M_1S_8	619.85	400.5	1020.35
M_2S_1	826.47	400.5	1226.97
M_2S_2	826.47	400.5	1226.97
M_2S_3	826.47	400.5	1226.97
M_2S_4	826.47	400.5	1226.97
M_2S_5	826.47	400.5	1226.97
M_2S_6	826.47	400.5	1226.97
M_2S_7	826.47	400.5	1226.97
M_2S_8	826.47	400.5	1226.97
M_3S_1	1033.09	400.5	1433.59
M_3S_2	1033.09	400.5	1433.59
M_3S_3	1033.09	400.5	1433.59
M_3S_4	1033.09	400.5	1433.59
M_3S_5	1033.09	400.5	1433.59
M_3S_6	1033.09	400.5	1433.59
M_3S_7	1033.09	400.5	1433.59
M_3S_8	1033.09	400.5	1433.59
M_4S_1	2450.0	565.4	3015.4
M_4S_2	2450.0	565.4	3015.4
M_4S_3	2450.0	565.4	3015.4
M_4S_4	2450.0	565.4	3015.4
M_4S_5	2450.0	565.4	3015.4
M_4S_6	2450.0	565.4	3015.4
M_4S_7	2450.0	565.4	3015.4
M_4S_8	2450.0	565.4	3015.4

and collected in clean polythene bags (Table 4). Samples of the same treatments were mixed thoroughly and the quantity was reduced by quartering for analysis.

Leaf nutrient analysis

Collection of leaf samples

The noni leaves were collected from the respective treatments and washed with distilled water and then dried (Table 5). The dried samples were powdered with pestle and mortar and used for analysis of nutrients. The leaf samples were analyzed at vegetative, flowering and harvesting stages.

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

Soil nutrient status

Available nitrogen

The main plot treatment M_2 (100% WRc through drip irrigation) recorded the highest soil available nitrogen content (198.92, 172.05 and 154.25 kg ha^{-1}) compared to the treatment M_4 (check basin method of irrigation) with 188.56, 156.88 and 136.88 kg ha^{-1} in vegetative, flowering and harvesting stages, respectively (Table 6 and Figure 1). Between the sub plots, the treatment S_7 (100% RD of NPK through inorganic fertilizers) registered the increased available nitrogen content of 208.52, 180.08 and 162.55 kg ha^{-1} and this was followed by S_4 (50% FYM + 50% VC) with 200.36, 171.98 and 153.49 kg ha^{-1} in vegetative, flowering and harvesting stages,

Table 4. Methods of soil nutrient analysis.

Estimation	Methods	Author
Available nitrogen	Alkaline permanganate	Subbiah and Asija (1956)
Available phosphorus	Colorimetric	Olsen et al. (1954)
Available potassium	Flame photometry	Stanford and English (1949)

Table 5. Methods of leaf nutrient analysis.

Estimation	Methods	Author
Nitrogen	Microkjeldahl	Piper (1966)
Phosphorus	Vanadamolybdate	Piper (1966)
Potassium	Flame photometry	Piper (1966)

respectively. The treatment, S_8 (no manure and no fertilizers) showed the lowest soil available nitrogen content with 165.00, 138.13 and 121.25 kg ha^{-1} at different stages. Among the interactions, the treatment combination M_2S_7 (100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers) exhibited the highest soil available nitrogen content (210.82, 184.03 and 167.20 kg ha^{-1}). Among the organic manure, applied treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) observed with soil available nitrogen content of 206.29, 179.32 and 162.28 kg ha^{-1}.

The soil available nitrogen content was found to be lowest in M_4S_8 (check basin method of irrigation + no manure and no fertilizers) at various stages with 162.48, 133.52 and 116.20 kg ha^{-1}.

Available phosphorus

The data pertaining to soil available phosphorus recorded during vegetative, flowering and harvesting stages revealed a decreasing trend from vegetative to harvesting stages invariably (Table 7). Among the different main plot treatments experimented, the treatment M_2 (100% WRc through drip irrigation) showed the highest soil available phosphorus content (28.74, 25.76 and 21.88 kg ha^{-1}) at vegetative, flowering and harvesting stages. The soil available phosphorus content was found to be the lowest in M_4 (check basin method of irrigation) with 24.91, 21.78 and 17.63 kg ha^{-1}. When sub plot treatments were rated based on their performance for this trait, it came to be known that application of 100% RD of NPK through inorganic fertilizers (S_7) resulted in the highest soil available phosphorus content of 30.72, 27.64 and 23.67 kg ha^{-1} followed by S_4 (50% FYM + 50% VC) with 28.68, 25.55 and 21.55 kg ha^{-1} in vegetative, flowering and harvesting stages, respectively. The soil available phosphorus content was found to be the lowest in S_8 (no manure and no fertilizers) with 20.24, 17.91 and 14.12 kg ha^{-1} at three growth stages, respectively. In the combined effect of treatments, M_2S_7 (100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers) expressed the highest soil available phosphorus content (31.93, 28.87 and 25.13 kg ha^{-1}) as against the lowest (19.52, 17.03 and 13.12 kg ha^{-1}) in M_4S_8 (check basin method of irrigation + no manure and no fertilizers) at vegetative, flowering and harvesting stages, respectively.

Among the organic manure combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) recorded with soil available phosphorus content of 30.89, 27.85 and 24.02 kg ha^{-1} in vegetative, flowering and harvestings stages, respectively.

Available potassium

Between the main plots, the treatment M_2 (100% WRc through drip irrigation) recorded the highest available potassium content (357.18, 336.42 and 326.38 kg ha^{-1}) as compared to that of M_4 (check basin method of irrigation) with 349.88, 328.97 and 318.74 kg ha^{-1} in vegetative, flowering and harvesting stages, respectively (Table 8). Among the sub plots, the treatment S_7 (100% RD of NPK through inorganic fertilizers) registered the increased soil available potassium content (363.12, 341.94 and 331.65 kg ha^{-1}) and this was followed by S_4 (50% FYM + 50% VC) with 358.08, 336.90 and 326.70 kg ha^{-1} in vegetative, flowering and harvesting stages, respectively. The lesser value (333.38, 315.16 and 305.90 kg ha^{-1}) was noticed in the treatment S_8 (no manure and no fertilizers) during three stages, respectively. Among the interactions, the treatment combination M_2S_7 (100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers) resulted in increased score (365.26, 344.17 and 333.94 kg ha^{-1}) for soil available potassium content. Regarding the organic manure applied treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM +

Table 6. Effect of different water regimes and organic manures on soil available nitrogen (kg ha^{-1}) content.

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	192.78	199.69	199.20	188.69	195.09	162.90	172.29	171.80	156.59	165.90	143.89	153.66	153.20	135.62	146.59
S_2	196.33	204.79	204.12	191.52	199.19	168.26	177.68	177.10	160.04	170.77	148.75	160.53	159.79	139.86	152.23
S_3	192.36	198.53	198.90	188.12	194.48	162.62	170.74	171.32	155.44	165.03	143.39	152.26	152.74	134.87	145.82
S_4	197.69	206.29	205.40	192.07	200.36	169.30	179.32	178.56	160.72	171.98	150.13	162.28	161.40	140.15	153.49
S_5	194.37	202.06	201.63	190.10	197.04	165.64	175.25	174.66	157.12	168.17	146.02	156.52	155.70	136.24	148.62
S_6	194.85	202.56	203.79	190.72	197.98	166.30	175.84	176.63	158.28	169.26	146.64	157.23	157.75	137.39	149.75
S_7	208.27	210.82	210.21	204.78	208.52	179.38	184.03	183.60	173.32	180.08	161.85	167.20	166.42	154.72	162.55
S_8	164.59	166.59	166.32	162.48	165.00	137.26	141.23	140.52	133.52	138.13	120.88	124.35	123.58	116.20	121.25
Mean	192.66	198.92	198.70	188.56	194.71	163.96	172.05	171.77	156.88	166.16	145.19	154.25	153.82	136.88	147.54
	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)	0.5085	0.6981	1.4014	1.3961		0.4366	0.5961	1.1976	1.1921		0.3906	0.5294	1.0647	1.0588	
CD at 5%	1.6182	1.4299	3.0800	2.8599		1.3895	1.2210	2.6337	2.4420		1.2432	1.0845	2.3435	2.1690	
CD at 1%	2.9703	1.9292	4.4409	3.8584		2.5505	1.6473	3.7996	3.2947		2.2820	1.4631	3.3836	2.9262	

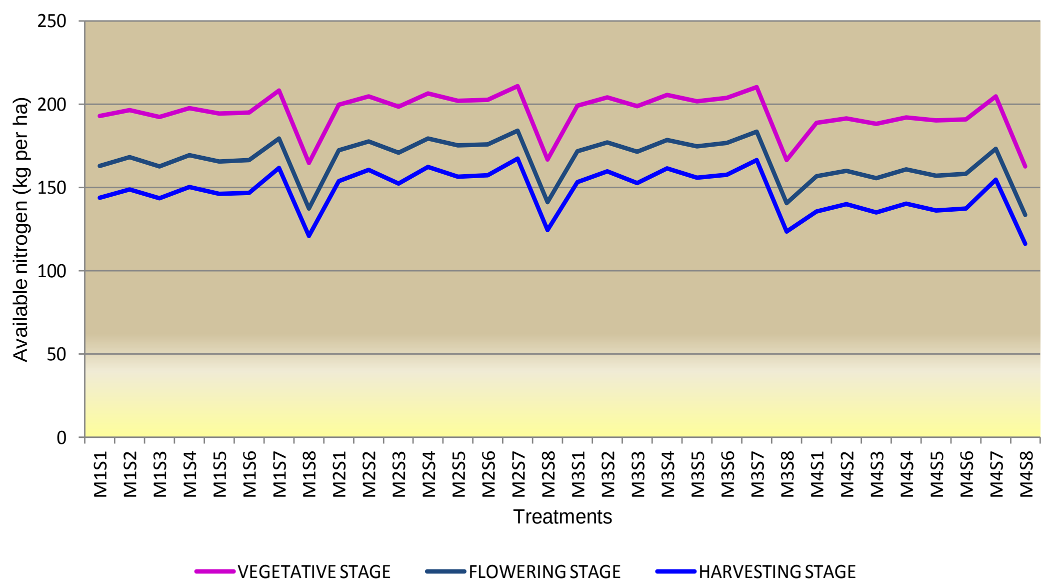

Figure 1. Effect of different water regimes and organic manures on soil available nitrogen (kg ha^{-1}) content.

Table 7. Effect of different water regimes and organic manures on soil available phosphorus (kg ha^{-1}) content.

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	26.21	28.55	28.96	24.36	27.02	23.05	25.43	25.84	21.13	23.86	18.95	21.49	21.78	17.04	19.82
S_2	27.21	30.29	30.12	25.50	28.28	24.06	27.17	26.98	22.28	25.12	19.89	23.23	23.04	18.08	21.06
S_3	26.60	28.34	28.12	24.70	26.94	23.41	25.25	25.03	21.46	23.79	19.30	21.20	20.96	17.24	19.68
S_4	27.54	30.89	30.58	25.69	28.68	24.39	27.85	27.49	22.48	25.55	20.28	24.02	23.60	18.29	21.55
S_5	26.83	29.20	29.39	25.01	27.61	23.64	26.08	26.25	21.77	24.44	19.47	22.13	22.30	17.63	20.38
S_6	27.03	29.90	29.68	25.43	28.01	23.85	26.79	26.56	22.20	24.85	19.68	22.85	22.62	17.98	20.78
S_7	30.36	31.93	31.54	29.06	30.72	27.29	28.87	28.53	25.85	27.64	23.15	25.13	24.78	21.63	23.67
S_8	20.05	20.79	20.58	19.52	20.24	17.68	18.65	18.27	17.03	17.91	13.85	14.96	14.53	13.12	14.12
Mean	26.48	28.74	28.62	24.91	27.19	23.42	25.76	25.62	21.78	24.14	19.32	21.88	21.70	17.63	20.13
	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)	0.0711	0.0981	0.1968	0.1962		0.0636	0.0871	0.1750	0.1743		0.0535	0.0729	0.1465	0.1458	
CD at 5%	0.2262	0.2009	0.4322	0.4018		0.2025	0.1785	0.3847	0.3569		0.1702	0.1493	0.3222	0.2986	
CD at 1%	0.4152	0.2710	0.6228	0.5421		0.3717	0.2408	0.5548	0.4816		0.3125	0.2015	0.4650	0.4029	

Table 8. Effect of different water regimes and organic manures on soil available potassium (kg ha^{-1}) content.

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	352.69	356.87	356.26	350.09	353.98	331.47	335.70	335.10	328.81	332.77	321.24	325.52	324.88	318.45	322.52
S_2	355.03	361.24	360.85	351.94	357.27	333.80	340.09	339.68	330.67	336.06	323.55	329.90	329.46	320.34	325.81
S_3	354.12	358.04	358.63	350.84	355.41	332.88	336.90	337.49	329.59	334.22	322.63	326.68	327.28	319.27	323.97
S_4	355.78	362.58	361.72	352.24	358.08	334.57	341.49	340.58	330.95	336.90	324.32	331.38	330.40	320.68	326.70
S_5	354.53	358.94	359.38	351.17	356.01	333.29	337.78	338.22	329.93	334.81	323.06	327.56	328.01	319.60	324.56
S_6	354.80	359.72	360.12	351.53	356.54	333.59	338.55	338.94	330.25	335.33	323.38	328.31	328.73	319.97	325.10
S_7	362.65	365.26	364.79	359.77	363.12	341.44	344.17	343.58	338.55	341.94	331.17	333.94	333.35	328.15	331.65
S_8	333.29	334.78	334.02	331.43	333.38	315.02	316.69	315.89	313.04	315.16	305.65	307.74	306.75	303.47	305.90
Mean	352.86	357.18	356.97	349.88	354.22	332.01	336.42	336.19	328.97	333.40	321.88	326.38	326.11	318.74	323.28
	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)	0.3738	0.5061	1.0179	1.0121		0.3524	0.4762	0.9581	0.9524		0.3419	0.4617	0.9290	0.9234	
CD at 5%	1.1897	1.0367	2.2408	2.0733		1.1216	0.9755	2.1096	1.9510		1.0882	0.9458	2.0458	1.8916	
CD at 1%	2.1838	1.3986	3.2357	2.7972		2.0587	1.3161	3.0468	2.6322		1.9975	1.2760	2.9549	2.5521	

Table 9. Effect of different water regimes and organic manures on leaf nitrogen content (%).

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	1.623	1.648	1.646	1.608	1.631	1.881	1.914	1.910	1.863	1.892	1.724	1.748	1.747	1.707	1.732
S_2	1.635	1.663	1.661	1.617	1.644	1.894	1.932	1.930	1.873	1.907	1.737	1.765	1.763	1.716	1.745
S_3	1.622	1.641	1.643	1.606	1.628	1.880	1.904	1.908	1.860	1.888	1.722	1.743	1.745	1.704	1.729
S_4	1.638	1.668	1.665	1.620	1.648	1.898	1.937	1.934	1.875	1.911	1.740	1.771	1.768	1.718	1.749
S_5	1.628	1.655	1.653	1.613	1.637	1.889	1.923	1.920	1.866	1.900	1.731	1.755	1.753	1.710	1.737
S_6	1.630	1.657	1.658	1.615	1.640	1.891	1.924	1.927	1.868	1.903	1.732	1.758	1.759	1.712	1.740
S_7	1.673	1.684	1.682	1.662	1.675	1.938	1.951	1.949	1.919	1.939	1.769	1.784	1.781	1.750	1.771
S_8	0.929	0.936	0.934	0.922	0.930	1.057	1.064	1.063	1.046	1.058	0.911	0.918	0.916	0.903	0.912
Mean	1.547	1.569	1.568	1.533	1.554	1.791	1.819	1.818	1.771	1.800	1.633	1.655	1.654	1.615	1.639
	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)	0.0015	0.0023	0.0045	0.0045		0.0017	0.0026	0.0052	0.0053		0.0016	0.0024	0.0048	0.0048	
CD at 5%	0.0048	0.0047	0.0098	0.0093		0.0055	0.0054	0.0114	0.0108		0.0050	0.0049	0.0104	0.0099	
CD at 1%	0.0088	0.0063	0.0140	0.0126		0.0102	0.0073	0.0162	0.0146		0.0092	0.0067	0.0148	0.0133	

50% VC) recorded with soil available potassium content of 362.58, 341.49 and 331.38 kg ha^{-1} in vegetative, flowering and harvesting stages, respectively.

The treatment combination M_4S_8 (check basin method of irrigation + no manure and no fertilizers) exhibited the least value (331.43, 313.04 and 303.47 kg ha^{-1}) of soil available potassium content.

Leaf nutrient status

Leaf nitrogen

A higher leaf nitrogen content of 1.569, 1.819 and 1.655 was exhibited by the treatment M_2 (100% WRc through drip irrigation) as against 1.533, 1.771 and 1.615% in M_4 (check basin method of irrigation) in vegetative, flowering and harvesting stages, respectively (Table 9). Between sub plot treatments, S_7 (100% RD of NPK through inorganic fertilizers) recorded the highest leaf nitrogen content (1.675, 1.939 and 1.771%) followed by S_4 (50% FYM + 50% VC) with 1.648, 1.911 and 1.7495 in vegetative, flowering and harvesting stages, respectively. The leaf nitrogen content was found to be the lowest (0.930, 1.058 and 0.912) with S_8 (no manure and no fertilizers) during different growth stages. Among the treatment combinations, M_2S_7 (100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers) recorded a greater nitrogen content (1.684, 1.951 and 1.784%). Between the organic manure applied treatment combination, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) showed the leaf nitrogen content of 1.668, 1.937 and 1.771%. The leaf nitrogen content was found to be the lowest with 0.922, 1.046 and 0.903 in M_4S_8 (check basin method of irrigation + no manure and no fertilizers).

Leaf phosphorus

In the main plot, the treatment, M_2 (100% WRc through drip irrigation) expressed a higher leaf phosphorus content (0.288, 0.320 and 0.307%) in vegetative, flowering and harvesting stages, respectively; while the treatment, M_4 (check basin method of irrigation) exhibited a phosphorous content of 0.261, 0.289 and 0.273% in various crop growth stages (Table 10). Likewise in the sub plots, the treatment S_7 (100% RD of NPK through inorganic fertilizers) resulted in the highest score for leaf phosphorus content (0.309, 0.342 and 0.330%) and this was followed by S_4 (50% FYM + 50% VC) with 0.292, 0.326 and 0.313% in vegetative, flowering and harvesting stages, respectively; while lesser content (0.203, 0.218 and

Table 10. Effect of different water regimes and organic manures on leaf phosphorus content (%).

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	0.272	0.288	0.291	0.260	0.278	0.303	0.319	0.323	0.289	0.309	0.288	0.306	0.310	0.273	0.294
S_2	0.281	0.302	0.300	0.270	0.288	0.313	0.338	0.335	0.300	0.322	0.298	0.326	0.322	0.283	0.307
S_3	0.275	0.286	0.284	0.263	0.277	0.305	0.318	0.315	0.293	0.308	0.291	0.304	0.302	0.277	0.294
S_4	0.283	0.309	0.305	0.271	0.292	0.314	0.347	0.342	0.302	0.326	0.299	0.335	0.329	0.287	0.313
S_5	0.277	0.292	0.294	0.266	0.282	0.308	0.325	0.328	0.295	0.314	0.295	0.312	0.315	0.278	0.300
S_6	0.280	0.297	0.296	0.268	0.285	0.310	0.332	0.330	0.297	0.317	0.296	0.320	0.318	0.281	0.304
S_7	0.305	0.319	0.316	0.296	0.309	0.335	0.356	0.353	0.323	0.342	0.323	0.344	0.340	0.311	0.330
S_8	0.202	0.209	0.208	0.194	0.203	0.217	0.224	0.222	0.210	0.218	0.198	0.205	0.202	0.191	0.199
Mean	0.272	0.288	0.287	0.261	0.277	0.301	0.320	0.319	0.289	0.307	0.286	0.307	0.305	0.273	0.292
	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)	0.0003	0.0004	0.0008	0.0008		0.0003	0.0004	0.0009	0.0009		0.0003	0.0004	0.0009	0.0009	
CD at 5%	0.0009	0.0008	0.0018	0.0016		0.0010	0.0009	0.0020	0.0018		0.0010	0.0009	0.0019	0.0017	
CD at 1%	0.0017	0.0011	0.0025	0.0022		0.0019	0.0012	0.0028	0.0025		0.0018	0.0012	0.0027	0.0023	

0.199%) were obtained from the treatment S_8 (no manure and no fertilizers). When interaction effects of these factors were rated based on their performance, it came to be known that application 100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers (M_2S_7) had resulted in the highest phosphorus content (0.319, 0.356 and 0.344%) while the lowest (0.194, 0.210 and 0.191%) was found to be with check basin method of irrigation + no manure and no fertilizers (M_4S_8).

Regarding the organic manures applied treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) recorded the leaf phosphorus content of 0.309, 0.347 and 0.335% in vegetative, flowering and harvesting stages, respectively.

Leaf potassium

In the main plot, the treatment M_2 (100% WRc through drip irrigation) expressed a higher leaf potassium content of 1.089, 1.316 and 1.206% in vegetative, flowering and harvesting stages, respectively (Table 11). The same was found to be the lowest (1.051, 1.275 and 1.164%) with check basin method of irrigation (M_4) in various growth phases of the crop. Pertaining to the sub plots, the treatment S_7 (100% RD of NPK through inorganic fertilizers) resulted in the superior score for leaf potassium content (1.131, 1.374 and 1.267%) and this was followed by S_4 (50% FYM + 50% VC) with 1.109, 1.352 and 1.242% in vegetative, flowering and harvesting stages, respectively; while lesser leaf potassium content (0.868, 0.979 and 0.862%) were obtained from the treatment S_8 (no manure and no fertilizers). Among the different treatment combinations, M_2S_7 (100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers) recorded a greater leaf potassium content (1.142, 1.387 and 1.280%). Regarding the organic manures applied treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) recorded the leaf potassium content of 1.132, 1.378 and 1.269% in different crop growth stages. The treatment combination comprising check basin method of irrigation + no manure and no fertilizers (M_4S_8) registered the lowest leaf potassium content in vegetative (0.859%), flowering (0.970%) and harvesting (0.853%) stages, respectively.

DISCUSSION

Soil available nutrient status

It was revealed that the application of 100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers (M_2S_7) recorded the highest available NPK in soil, supporting the concept of readily available nature of inorganic fertilizers. The mobility of nutrients was well pronounced under

Table 11. Effect of different water regimes and organic manures on leaf potassium content (%).

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	1.081	1.102	1.099	1.065	1.087	1.323	1.344	1.340	1.305	1.328	1.212	1.234	1.231	1.195	1.218
S_2	1.093	1.125	1.123	1.077	1.105	1.335	1.368	1.366	1.318	1.347	1.224	1.259	1.256	1.206	1.236
S_3	1.086	1.107	1.109	1.069	1.093	1.327	1.348	1.351	1.310	1.334	1.215	1.239	1.242	1.198	1.224
S_4	1.096	1.132	1.128	1.079	1.109	1.337	1.378	1.372	1.319	1.352	1.227	1.269	1.263	1.208	1.242
S_5	1.089	1.112	1.114	1.071	1.097	1.329	1.354	1.356	1.313	1.338	1.218	1.244	1.247	1.202	1.228
S_6	1.091	1.116	1.119	1.074	1.100	1.332	1.359	1.363	1.315	1.342	1.220	1.250	1.254	1.205	1.232
S_7	1.128	1.142	1.140	1.115	1.131	1.373	1.387	1.384	1.353	1.374	1.264	1.280	1.276	1.244	1.267
S_8	0.868	0.874	0.872	0.859	0.868	0.978	0.986	0.983	0.970	0.979	0.860	0.869	0.867	0.853	0.862
Mean	1.067	1.089	1.088	1.051	1.074	1.292	1.316	1.314	1.275	1.299	1.180	1.206	1.205	1.164	1.189
	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)	0.0011	0.0015	0.0031	0.0031		0.0013	0.0019	0.0038	0.0038		0.0012	0.0017	0.0034	0.0034	
CD at 5%	0.0035	0.0032	0.0068	0.0063		0.0042	0.0038	0.0082	0.0077		0.0038	0.0035	0.0075	0.0070	
CD at 1%	0.0065	0.0043	0.0098	0.0085		0.0077	0.0052	0.0118	0.0104		0.0070	0.0048	0.0108	0.0095	

drip irrigation system. Nutrients were carried along with the water movement and concentrated near the outer periphery of the wetting zone. Similar reports were given to Prakash (2010). Combined application of 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) showed an increase in soil available nitrogen content compare to M_4S_8 (check basin method of irrigation + no manure and no fertilizers). This is due to continuous availability of higher soil moisture content under drip irrigation which helped to solubilize the plant nutrient near the root zone and favoured easy availability and absorption of plant nutrients by the noni crop. Added organic manures not only acted as source of nutrients but also influenced their availability. Cumulative effects of this treatment combination seem to ensure adequate supply of nutrients slowly and steadily throughout the crop growth period at optimum level. Farmyard manure could supply 5.0 Kg N t^{-1} (Katyayan, 2001). The increase in the contents of total nitrogen might be attributed to the better availability of nitrogen coupled with retarded nitrification process by restricting the movement of nitrates to lower depth, enabling the slow availability of nitrogen to plants.

Optimum availability of nitrogen in soil under farmyard manure addition could be due to favourable congenial microbial activity and the enhanced biomass addition to the soil and also as result of improved soil physical properties. Organic nitrogen and P_2O_5 availability in the soil increased with the application of farmyard manure, due to the increase of decomposition of products of organic matter. This is in agreement with the previous works of Ismail et al. (1998). Singh et al. (1992) opined that the addition of organic matter influences the transformation and availability of N through its impact on chemical and biological properties of soil. Moreover, the beneficial microbial biomass would have been multiplied in the applied organic manure itself and released into soil which might have contributed to increased N for reuse by the succeeding crop. Similar results were also recorded by Padmapriya (2004) and Vanilarasu (2011). Regarding their superior chemical attributes, Arancon and Edwards (2005) reported that vermicomposts, usually contained more mineral elements than commercial plant growth media and many of these elements were changed to forms more that could be readily available for taken up by the plants such as nitrates, available phosphorus and exchangeable potassium, calcium and magnesium. Lowest nutrient availability with check basin method of irrigation may be due to leaching and volatilization losses of nutrients under conventional check basin method of irrigation which leads to quick depletion of nutrients from the root zone which resulted in low availability of nutrients. Prakash (2010) reported that in surface irrigation, the plant nutrients leached beyond the root zone due to higher quantity of irrigation water and also observed leaching of plant nutrients when downward soil moisture movement exceeded effective root zone.The available phosphorus was found to be higher in the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) compare to M_4S_8 (check basin method of irrigation + no manure and no fertilizers), which might be due to the result of reduced fixation of native phosphorus through the release of organic acids during the decomposition and increased its mobilization in soil. Usually, farmyard manure with a narrow CN ratio produces more chelated phosphates, which are more soluble in water. This easily available form might have triggered the synthesis of more protein in roots as reported by Upadhyay and Misra (1999) in turmeric. Higher phosphorus content in vermicompost treated plot may be due to increased phosphatase activity from the direct action of gut enzymes of earthworm and indirectly by the stimulation of microorganisms (Arancon and Edwards, 2005). Moreover, vermicompost possesses high ‘P’ content. Application of vermicompost in this treatment could be responsible for the higher soil ‘P’ content. The inoculation of phosphobacteria resulted in the increased availability of phosphorous, since these bacteria helps to degrade the complex forms of phosphate into more soluble and simple forms of phosphorous. The result of present investigation is in agreement with that of Vanilarasu (2011).

The applied organic inputs form a cover on sesquioxides, thus reducing the phosphate fixing capacity of the soil and promote solubilisation of insoluble P fractions resulting into release of available P. The potassium availability was also higher in the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) compare to M_4S_8 (check basin method of irrigation + no manure and no fertilizers). The increase in exchangeable potassium could be due to increased potassium release from farmyard manure. Normally, all the organic manures improve the fertility status of soil due to slow release of nutrients thereby avoiding the wastage. Such manures augment the humus content in soil. This is in concurrence with previous findings of Padmanabhan (2003) in ashwagandha and Vanilarasu (2011) in banana. The combined application of farmyard manure and vermicompost in the present treatment would be the reason which might have caused the mineralization by solublising the insoluble components through the action of organic acids (malic, succinic and oxalic acids) released during decomposition process thereby minimizing losses due to fixation. The increased nutrient in organic manure amended soil was due to the dissolution of native insoluble compounds and reduction of loss through immobilization and chelating action.

The decomposing FYM would have produced organic acids (malic, succinic and oxalic acids) thereby reducing the pH which would have contributed to the formation of soluble hydroxy complexes of Zn, Mn and Fe. Similar line of result was obtained by Nipunage et al. (1996).

Leaf nutrient status

Plant leaf nutrient analysis is a more helpful tool for assessing the content of nutrient in plant system. The actual nutrient concentrations, contents and the rate of changes of these nutrients during vegetative growth and transitional period between the vegetative and the reproductive phase might eventually determine the final reproductive mass. Nutrient content plays a critical role for higher yield and quality of fruits in noni. Nitrogen is an important constituent of amino acids, proteins, enzymes, nucleic acids and chlorophyll content. Phosphorus plays a key role in energy transfer system of plants. Potassium being a protoplasmic factor is also an essential plant nutrient. Many enzymes are activated by potassium and it is also involved in photo and oxidative phosphorylation, thus augmenting the synthesis of energy required for fruit growth. In the present study, application of 100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers (M_2S_7) led to accumulation of higher nutrient content in leaves. This might be due to increased nutrient uptake and better moisture availability which could have contributed to higher growth and development of plants (Prakash, 2010). Drip irrigation system provide conducive environment for plant growth and nutrient uptake. Nutrient loss under drip irrigation was meager compared to check basin method of irrigation.

Nutrients applied in the form of inorganic fertilizers may be easily available to plants. This may be the reason for enhancement in leaf nutrient status. Increased nutrient status in leaves may also be attributed due to accumulation of photosynthates (Prakash, 2010). Application of 100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers (M_2S_7) registered the highest nutrient content in leaf. Application of macro nutrients had resulted in the enhanced absorption of nutrient by noni crop that ultimately led to higher leaf nutrient status. It is also possible that the application of 100% WRc through drip irrigation + 100% RD of NPK through inorganic fertilizers (M_2S_7) might have activated the physiological processes for the rapid absorption and utilization of nutrients for the primary metabolic processes. Among the organic manure treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the increased leaf nutrient status compared to M_4S_8 (check basin method of irrigation + no manure and no fertilizers), which might be due to availability of adequate moisture required by the crops to absorb the available nutrients effectively. The continuous availability of required soil moisture content under drip irrigation system may be helped to solubilize the plant nutrient near the root zone and favoured easy absorption of plant nutrients by the noni plant under 100% WRc through drip irrigation. The cyclic regulation and continuous wetting of soil through drip irrigation maintained optimum moisture in the crop root zone. Due to this, the force exerted by the plant to extract water and nutrients would be less.

Added organic manures namely, farmyard manure and vermicompost not only acted as a source of nutrients, but also had influenced their availability. Cumulative effects of these treatments seemed to be adequate supplier of nutrients slowly and steadily in optimum level throughout the crop growth period. The increase in leaf phosphorus content in the M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) over M_4S_8 (check basin method of irrigation + no manure and no fertilizers) may be due to fact that application of FYM along with biofertilizers may be attributed to better availability of P in rhizosphere (Shashidhara, 2000). The complex organic anions chelate Al^{+3}, Fe^{+3} and Ca^{+2}; and decrease phosphate precipitating power of these cations and thereby increase the phosphorus availability. Also, phosphobacteria might have helped in solubilising phosphorous that were immobilized and fixed in soil to utilizable form and aided in easy uptake (Krishnamoorthy and Rema, 2004). Moreover, increased root proliferation due to the application of VAM also might had contributed to the increased uptake of 'P' content from the soil. Similarly, this may also be due to better soil moisture regime prevailing in root zone through drip irrigation which is crucial for better nutrient availability and assimilation as observed by Chauhan et al. (2005) in apple. The treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered higher leaf potassium content over M_4S_8 (check basin method of irrigation + no manure and no fertilizers). The optimum potassium level of the soils of the experimental plot might have also contributed to this trend. The reason for higher concentration of potassium under various treatments may be the consequence of higher demand of the expanding foliage and increased absorption to maintain the growth (Alexander and Crizinszky, 1992).

From the present study, it could be concluded that application of 100% WRc through drip irrigation + 100% recommended dose of NPK through inorganic fertilizers (M_2S_7) resulted in improved soil and leaf nutrient status of noni.

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