Global Science Research Journals

ISSN: 0274-3248 Vol. 3 (2), pp. 309-319, February, 2017.

http://www.globalscienceresearchjournals.org/

Global Journal of Medicinal Plants Research

Full Length Research Paper

Effect of water regimes and organic manures on indole acetic acid (IAA)

Munimu Khan and Anand singh

Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam, Theni District-625604, Tamil Nadu, India.

Accepted 07 January, 2017

An experiment was conducted at Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam in split plot design with irrigation regimes on main plot (four levels) and organic manures on sub plot (eight levels) with two replications. Among the different treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% farmyard manure + 50% vermicompost) exhibited superior performance for leaf area, light transmission ratio, chlorophyll stability index, relative water content and fruit yield as against the poor performance by M_4S_8 (check basin method of irrigation + no manures and no fertilizers) at different growth phases. Indole acetic acid (IAA) oxidase activity was found to be the lowest in M_2S_4 (100% WRc through drip irrigation + 50% farmyard manure + 50% vermicompost) as against the highest in M_4S_8 (check basin method of irrigation + no manures and no fertilizers).

Key words: *Morinda citrifolia,* IAA oxidase, leaf area, light transmission ratio, chlorophyll stability index, relative water content, yield.

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). Cultivation of medicinal and herbal plants has assumed greater significance in recent days due to the tremendous potential, they offer in formulating newer drug formulations against many diseases. Chemical residue free plant based drugs are much valued than that obtained from plants cultivated inorganically (Padmanabhan, 2003).

*Corresponding author: E-mail: udemba.dave@yahoo.com

Valid information related to organic production techniques in medicinal plants, especially for noni is scanty. Hence, the field level study on the “Development of organic production techniques for noni (*Morinda citrifolia*) under varying water regimes through drip irrigation for higher yield” was conducted at Horticultural College and Research Institute, TNAU, Periyakulam.

Morinda citrifolia L., popularly known as Indian mulberry or Indian noni belonging 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 Island societies (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 total fats. About 160 phytochemical compounds have been identified in the noni plant (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, AIDS, cancers, gastric ulcers, sprains, mental depression, senility, poor digestion, atherosclerosis, blood vessel problems and drug addiction. Current trends reflect that people have a more inclination towards herbal medicines for its healing properties and no side effects. Noni best suits the current proposition where it has proved that it has got tremendous medicinal properties and is being used even in the treatment of cancer. Looking at the wide range of prospects that noni can offer in terms of medicinal properties, it is quite clear that the plant can be exploited for the benefit of human race. Given the conditions that are required for the noni to grow, it would be a good idea if its cultivation is encouraged in the state. If successful, it may give a boost to the local economy through commercialization.

Any crop management practice should aim in keeping the physiological process of the plants as an active stage and plant enzymatic activities in favourable condition so that the plants can produce biomass inturn yield with the least destructive processes. Indole acetic acid (IAA), a premier bioregulator, regulates the apical dominance and initiation of vegetative and flower buds in various crop plants. The amino acid tryptophan and zinc level in the leaves influences the IAA. IAA oxidase is the enzyme responsible for destruction of auxin through the process of oxidation. Therefore, the enzymatic activity causes reduction in auxin content and thereby decreases the normal growth of the plant. Total leaf area at any stage of the crop growth is an important aspect of noni as it has a close association with photosynthetic efficiency, reflecting on biomass production. Greater leaf area aids the plant to synthesize more metabolites exhibiting high photosynthetic rate during the period of growth and development (Mahadevan, 1988). A higher photosynthetic activity is a good indication of physiological efficiency in plants. This primarily depends upon the chlorophyll content in the leaves. This content in leaves indicates the efficiency of photo-synthesis where the solar energy is converted into chemical energy. A slight fluctuation in chlorophyll content is enough to trigger changes in physiological processes of the plants particularly photosynthesis.

Relative water content represents the ability of the plants to maintain its tissue water status even under stress situations and the plants retaining more tissue water are expected to perform better through maintaining proper hydration of plant protoplasm and turgidity of the assimilatory cells. Yield is a complex trait influenced by many factors. Apart from modern day cultivars, nutrient management system plays a crucial role on yield. Yield per plant is the culmination of the interplay of several factors like morphological traits, physiological parameters, soil biological properties, fruit characters and yield parameters. The purpose of all improved cultural operations is to manipulate these parameters thereby to attain increased yield level in crops.

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.

a. Statistical design: Split plot design
b. Factors: 2
c. Replications: 2
d. Spacing: 3.6 m x 3.6 m
e. Number of plants per replication: 5

Treatment details

Main plot (Irrigation)

M1 - 75% WRc (Computed water requirement through drip irrigation)
M2 - 100% WRc (Computed water requirement through drip irrigation)
M3 - 125% WRc (Computed water requirement through drip irrigation)
M4 - Check basin method of irrigation (5 cm depth)

Sub plot (Organic manures)

S1 - 100% Farmyard manure (FYM)
S2 - 100% Vermicompost (VC)
S3 - 100% Coir Pith Compost (CPC)
S4 - 50% FYM + 50% VC
S5 - 50% FYM + 50% CPC
S6 - 50% VC + 50% CPC
S7 - 100% recommended dose (RD) of NPK through inorganic fertilizers (60:30:30 g NPK plant-1)

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

Property	Value
Chemical property	
Available nitrogen (kg ha^{-1})	173
Available phosphorus (kg ha^{-1})	24
Available potassium (kg ha^{-1})	340
Physico-chemical property	
EC (dSm^{-1})	0.32
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

S8 - 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 the 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

$WR_c = CPE \times K_p \times K_c \times A \times W_p$ lit $plant^{-1}$ Where

WR_c = Computed water requirement (lit $plant^{-1}$)
CPE = Cumulative Pan Evaporation for two days (mm)
K_p = Pan Co-efficient (0.75)
K_c = Crop factor (0.90 for vegetative stage, 0.95 for flowering and harvesting stage) (Allen et al., 1998)
A = Area occupied by the noni tree (3.6 m x 3.6 m)
Wp = Wetting percentage (40)

The quantity of water applied during the study period is presented in Table 3.

Observations

IAA oxidase

The IAA oxidase enzyme activity in the leaf sample was determined colorimetrically at 540 nm as per the method of Parthasarathy et al. (1970). The OD values were referred to a standard curve using auxin (IAA – 10 to 100 µg/l) and expressed as µg un-oxidized auxin g^{-1} h^{-1} of the fresh leaf sample.

Leaf area per plant

The leaf area was calculated by using graph sheet and expressed in cm^2.

Light transmission ratio (LTR)

LTR measurements were made by placing the Lux meter above the canopy and also on the ground surface (Salki, 1963) and the ratio is expressed in per cent.

$$LTR\ (\%) = \frac{I_1}{I_0} \times 100$$

Where: I_0, Light intensity above the canopy; I_1, Light intensity at the ground surface

5 - 10 measurements were made in one canopy and average values were obtained.

Chlorophyll stability index (CSI)

CSI was assessed following the method of Murty and Majumder (1962). Two clean test tubes were taken (control and treatment). 250 mg of fresh leaf samples were weighed and cut into 8 to 10 leaf bits and transferred to test tubes. 20 ml of distilled water was added to the control test tube and 20 ml of hot water was added to the treatment test tube. The treatment test tube was kept in hot water bath for exactly 30 min. The other tube was kept as control. After completion of the reaction time, the leaf bits were taken from test tubes and macerated with 10 ml of 80% acetone. The contents were centrifuged at 3000 rpm for 10 min. The supernatant was collected and volume was made to 25 ml by using 80% acetone. The optical density was measured at 652 nm in a spectrophotometer.

$$CSI\ (\%) = \frac{\text{Total chlorophyll content (treatment)}}{\text{Total chlorophyll content (control)}} \times 100$$

Relative water content (RWC)

The relative water content of leaves was calculated as per the method suggested by Barrs and Weatherly (1962) to find out the percentage of water held by leaves relative to fully turgid tissue. Leaves were punched uniformly and the fresh weight of 20 leaf discs was recorded. Then the leaf discs were made to float in water for 2 h, after which the turgid weight was recorded after removing the excess water by blotting them thoroughly. The dry weight was recorded after drying in hot air oven at 70°C.

$$RWC\ (\text{per cent}) = \frac{\text{Fresh weight - dry weight}}{\text{Turgid weight – dry weight}} \times 100$$

Table 3. Quantity of water used during the study period.

Treatment	Water applied (mm)	Effective rainfall (mm)	Total water used (mm)
M_1S_1 to M_1S_8	619.85	400.5	1020.35
M_2S_1 to M_2S_8	826.47	400.5	1226.97
M_3S_1 to M_3S_8	1033.09	400.5	1433.59
M_4S_1 to M_4S_8	2450.0	565.4	3015.4

Fruit yield per hectare

The yield was recorded after weighing fully matured fruits at each harvest, summed and expressed in tones.

Statistical analysis

The statistical analysis of data collected 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

IAA oxidase activity

Among the irrigation treatments, M_2 (100% WRc through drip irrigation) registered lower values for IAA oxidase activity (25.75, 30.77 and 28.70 µg unoxidized auxin g^{-1} h^{-1}) in vegetative, flowering and harvesting stages (Table 4). The IAA oxidase activity was found to be the highest (21.94, 23.56 and 20.56 µg unoxidized auxin g^{-1} h^{-1}) with check basin method of irrigation (M_4). Among the sub plots, S_4 (50% FYM + 50% VC) recorded the lower score (25.89, 30.42 and 28.18 µg unoxidized auxin g^{-1} h^{-1}) for IAA oxidase activity. The IAA oxidase activity was found to be the highest (19.94, 20.63 and 17.30 µg unoxidized auxin g^{-1} h^{-1}) with the treatment S_8 (no manure and no fertilizers). Between the interaction, the treatment combination, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) exhibited the least IAA oxidase activity (28.72, 35.78 and 34.12 µg unoxidized auxin g^{-1} h^{-1}) in vegetative, flowering and harvesting stages respectively as against the highest IAA oxidase activity (18.82, 19.35 and 15.78 µg unoxidized auxin g^{-1} h^{-1}) in M_4S_8 (check basin method of irrigation + no manure and no fertilizers).

Leaf area

There was a progressive increase in leaf area per plant in all the treatments as the age of the crop advanced (Table 5 and Table 6). The treatment M_2 (100 per cent WRc through drip irrigation) produced the highest leaf area per plant (23670.19, 69669.69 and 174016.14 cm^2) in vegetative, flowering and harvesting stages respectively. Among the main plots, M_4 (check basin method of irrigation) exhibited the lowest leaf area per plant (8561.51, 23072.83 and 67017.29 cm^2) in all stages of crop growth. Regarding the various manure treatments, combined application of 50% FYM + 50% VC (S_4) registered more leaf area per plant in vegetative (23027.16 cm^2), flowering (68171.99 cm^2) and harvesting (179726.75 cm^2) stages. While S_8 (no manure and no fertilizers) showed the lowest leaf area per plant of 5916.31, 14687.42 and 41619.91 cm^2 in these three stages respectively. Among the interactions, the treatment combination of M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) produced the highest leaf area per plant (33655.16, 100507.68 and 271346.10 cm^2) in vegetative, flowering and harvesting stages respectively. Leaf area per plant was found to be the lowest (4531.74, 11692.80 and 33166.92 cm^2) in the treatment combination M_4S_8 (check basin method of irrigation + no manure and no fertilizers).

Light transmission ratio (LTR)

Among the main plot, M_2 (100 per cent WRc through drip irrigation) exhibited the highest LTR during vegetative (6.91%), flowering (9.42%) and harvesting (14.48%) stages (Table 7). LTR wasfound to be the lowest in the M_4 (check basin method of irrigation) during vegetative (4.94%), flowering (7.36) and harvesting (11.26%) stages. Application of 50% t FYM + 50% VC (S_4) had resulted in the highest LTR of 6.78, 9.36 and 14.34%. While S_8 (no manure and no fertilizers) registered the least score for LTR (4.28, 6.51 and 9.74%). Between the interactions, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) recorded the utmost LTR (7.89, 10.64 and 16.12%) in vegetative, flowering and harvesting stages respectively. The lowest light transmission ratio in vegetative (4.02%), flowering (6.10%) and harvesting (9.16%) stages was noticed from the treatment M_4S_8 (check basin method of irrigation + no manure and no fertilizers).

Chlorophyll stability index (CSI)

Application of 100% WRc through drip irrigation exhibited superior performance for CSI during vegetative (69.39 %), flowering (71.01%) and harvesting (71.97%) stages (Table 8). The treatment M_4 (check basin method of irri-gation) registered the lowest CSI (60.95, 62.03 and 62.64%)

Table 4. Effect of different water regimes and organic manures on leaf IAA oxidase activity (µg unoxidized auxin g^{-1} h^{-1}).

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	24.27	26.20	26.07	22.27	24.70	27.22	31.42	31.35	23.90	28.47	24.71	29.58	29.44	21.02	26.19
S_2	24.51	26.84	27.18	22.50	25.26	27.48	32.74	33.04	24.38	29.41	25.06	30.78	31.14	21.40	27.10
S_3	23.90	25.33	25.17	22.05	24.11	26.63	30.26	30.13	23.66	27.67	23.76	28.26	28.2	20.75	25.24
S_4	24.56	28.72	27.53	22.74	25.89	27.69	35.78	33.52	24.68	30.42	25.24	34.12	31.56	21.79	28.18
S_5	24.07	25.63	25.58	22.16	24.36	26.84	30.74	30.62	23.84	28.01	23.88	28.76	28.69	20.86	25.55
S_6	24.20	26.62	26.75	22.39	24.99	27.11	32.26	32.35	24.15	28.97	24.49	30.38	30.47	21.25	26.65
S_7	24.38	26.30	26.37	22.59	24.91	27.40	31.83	32.05	24.53	28.95	24.82	29.92	30.12	21.66	26.63
S_8	20.03	20.39	20.51	18.82	19.94	20.66	21.10	21.42	19.35	20.63	17.42	17.83	18.18	15.78	17.30
Mean	23.74	25.75	25.65	21.94	24.27	26.38	30.77	30.56	23.56	27.82	23.67	28.70	28.48	20.56	25.35
	M	**S**	**M@S**	**S@M**		**M**	**S**	**M@S**	**S@M**		**M**	**S**	**M@S**	**S@M**	
SE (d)	0.1300	0.1741	0.3506	0.3481		0.1507	0.2009	0.4049	0.4018		0.1376	0.1843	0.3712	0.3685	
CD @ 5%	0.4136	0.3566	0.7729	0.7132	-	0.4795	0.4115	0.8930	0.8230	-	0.4380	0.3775	0.8182	0.7549	-
CD @ 1%	0.7592	0.4811	1.1173	0.9622		0.8802	0.5552	1.2916	1.1104		0.8040	0.5092	1.1829	1.0185	

Table 5. Effect of different water regimes and organic manures on leaf area per plant (cm^2) at vegetative and flowering stage.

Treatment	Vegetative stage					Flowering stage				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	13667.28	24116.40	23313.42	8551.40	17412.13	36396.27	69812.82	69927.41	22731.32	49716.96
S_2	15954.15	28803.36	29884.62	9613.62	21063.94	43875.84	87818.76	90375.75	27135.04	62301.35
S_3	12060.00	20079.72	19359.71	7777.83	14819.32	32347.20	59114.50	55850.22	18969.12	41570.26
S_4	16652.34	33655.16	31205.60	10595.52	23027.16	48423.60	100507.68	93812.88	29943.76	68171.99
S_5	12727.94	22108.80	21559.10	8303.62	16174.87	34870.50	64450.98	62651.40	20761.20	45683.52
S_6	15141.36	27960.88	27089.82	9031.68	19805.94	40429.87	82952.59	80953.95	24334.50	57167.73
S_7	17763.95	25963.84	25532.01	10086.65	19836.61	52256.51	76283.82	77347.20	29014.92	58725.61
S_8	6028.00	6673.37	6432.12	4531.74	5916.31	14897.44	16416.40	15743.04	11692.80	14687.42
Mean	13749.38	23670.19	23047.05	8561.51	17257.03	37937.15	69669.69	68332.73	23072.83	49753.10
	M	**S**	**M@S**	**S@M**		**M**	**S**	**M@S**	**S@M**	
SE (d)	108.5423	136.3278	277.1821	272.6557		318.9415	399.9741	813.4194	799.9481	
CD @ 5%	345.4354	279.2624	615.9982	558.5247	-	1015.0299	819.3317	1808.0773	1638.6633	-
CD @ 1%	634.0821	376.7654	896.8739	753.5308		1863.1916	1105.3971	2632.9650	2210.7942	

during three different crop growth stages. Application of 50% FYM + 50% VC (S_4) recorded the highest CSI (69.41, 71.05 and 71.96%) in vegetative, flowering and harvesting stages. The lowest CSI of 57.29, 58.04 and 58.43% was noticed from the treatment S_8 (no manure and no fertilizers). Among the interaction, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) registered the highest CSI in vegetative (75.60%), flowering (77.82%) and harvesting (78.96%) stages. Check basin method of irrigation + no manure and no

Table 6. Effect of different water regimes and organic manures on leaf area per plant (cm^2) at harvesting stage.

Treatment	Harvesting stage				
	M_1	M_2	M_3	M_4	Mean
S_1	104543.38	166551.04	173287.11	67626.13	128001.92
S_2	116114.70	214457.90	226670.66	78230.88	158868.54
S_3	93088.50	138431.80	132159.68	57006.42	105171.60
S_4	120265.00	271346.10	242427.48	84868.42	179726.75
S_5	98895.80	155663.65	147420.63	61659.00	115909.77
S_6	109195.24	206600.68	200267.94	73014.92	147269.70
S_7	126145.80	190746.72	192225.88	80565.59	147421.00
S_8	40498.92	48331.22	44482.56	33166.92	41619.91
Mean	101093.42	174016.14	169867.74	67017.29	127998.65
	M	**S**	**M@S**	**S@M**	
SE (d)	825.5203	1011.5017	2064.5723	2023.0034	-
CD @ 5%	2627.2142	2072.0227	4603.5247	4144.0455	
CD @ 1%	4822.5216	2795.4588	6721.8422	5590.9177	

fertilizers (M_4S_8) treatment combination exhibited the lowest chlorophyll stability index in vegetative (54.10%), flowering (54.68%) and harvesting (54.89%) stages.

Relative water content (RWC)

Among the main plot treatments, M_2 (100% WRc through drip irrigation) recorded superior values on RWC in vegetative (62.97%), flowering (66.62%) and harvesting (68.52%) stages (Table 9). RWC was found to be the lowest in the M_4 (check basin method of irrigation) with 43.84, 45.44 and 46.3% in three different stages respectively. On comparison of the performance of the sub plot treatments, S_4 (50% FYM + 50% VC) exhibited the superior performance with 63.80, 67.43 and 69.20% RWC during vegetative, flowering and harvesting stages respectively. The lowest RWC of 38.20, 38.96 and 39.45% was recorded with no manure and no fertilizers treatment (S_8). Among the interactions, the treatment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) exhibited superior scores for RWC (81.24, 86.27 and 89.84 %) at various stages of crop growth. In the treatment M_4S_8 (check basin method of irrigation + no manure and no fertilizers), the lowest RWC (33.26, 34.02 and 34.41%) was recorded during entire crop growth period.

Fruit yield

When main plot treatments were rated based on their performance (Table 10), it was known that application of 100% WRc through drip irrigation (M_2) had resulted in the highest fruit yield per hectare (19.35 t) while the lowest (10.91 t) was found to be with check basin method of irrigation (M_4). Regarding the sub plots, application of 50% FYM + 50 % VC (S_4) exhibited the superior scores for fruit yield per hectare (19.96 t). While the treatment S_8 (no manure and no fertilizers) showed very poor performance for fruit yield per hectare with 5.66 t. In the combined effect of treatments, the treatment combination comprising 100% WRc through drip irrigation + 50% FYM + 50% VC (M_2S_4) recorded the highest scores for fruit yield per hectare with 25.68 t. Fruit yield per hectare was found to be the lowest in M_4S_8 (check basin method of irrigation + no manure and no fertilizers) with 4.87 t.

DISCUSSION

IAA oxidase estimated at various crop growth stages revealed differences among water regimes and organic manures. Among the various treatment combinations, M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) exhibited the lowest IAA oxidase activity. IAA oxidase is an enzyme very sensitive to both biotic and abiotic stresses. It is responsible for inactivation of auxin in plant system. Galston and Dalberg (1954), measured IAA oxidase activity and growth response of 7 to 8 days old etiolated pea seedlings, and they revealed that IAA oxidase activity was low in regions of high auxin content. IAA stimulates the cellulose synthetase and regulates cell wall synthesis (Aref and Ray, 1967). It revealed that the high yielding plants had favorable auxin balance through the destruction of the IAA oxidative degradation. In the plants with lesser levels of available moisture and nutrients in soils the IAA synthesis might have been insufficient for encouraging IAA oxidative metabolism.

Combined application of 100 per cent WRc through drip

Table 7. Effect of different water regimes and organic manures on light transmission ratio of noni leaves.

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	5.73	7.13	7.02	4.98	6.22	8.35	9.50	9.48	7.50	8.71	13.02	14.85	14.82	11.46	13.54
S_2	6.11	7.65	7.57	5.15	6.62	8.55	10.23	10.18	7.64	9.15	13.42	15.54	15.43	11.70	14.02
S_3	5.52	6.60	6.49	4.85	5.87	8.20	9.15	9.11	7.24	8.43	12.79	14.29	14.23	11.19	13.13
S_4	6.19	7.89	7.72	5.31	6.78	8.63	10.64	10.37	7.78	9.36	13.54	16.12	15.78	11.92	14.34
S_5	5.60	6.90	6.79	4.93	6.06	8.29	9.32	9.31	7.39	8.58	12.91	14.64	14.48	11.35	13.35
S_6	5.92	7.48	7.37	5.07	6.46	8.49	10.06	9.94	7.55	9.01	13.26	15.38	15.34	11.53	13.88
S_7	6.28	7.30	7.22	5.19	6.50	8.74	9.76	9.80	7.70	9.00	13.76	15.10	15.16	11.78	13.95
S_8	4.26	4.36	4.48	4.02	4.28	6.49	6.68	6.76	6.10	6.51	9.74	9.92	10.14	9.16	9.74
Mean	5.70	6.91	6.83	4.94	6.10	8.22	9.42	9.37	7.36	8.59	12.81	14.48	14.42	11.26	13.24
	M	**S**	**M@S**	**S@M**		**M**	**S**	**M@S**	**S@M**		**M**	**S**	**M@S**	**S@M**	
SE(d)	0.0334	0.0443	0.0893	0.0885		0.0467	0.0619	0.1249	0.1238		0.0709	0.0957	0.1925	0.1913	
CD @ 5%	0.1062	0.0907	0.1970	0.1813	-	0.1486	0.1268	0.2756	0.2537	-	0.2256	0.1960	0.4240	0.3919	-
CD @ 1%	0.1949	0.1223	0.2851	0.2446		0.2727	0.1711	0.3989	0.3423		0.4142	0.2644	0.6124	0.5288	

Table 8. Effect of different water regimes and organic manures on chlorophyll stability index (per cent) of noni leaves.

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	65.68	69.58	69.76	61.43	66.61	66.95	71.25	71.37	62.57	68.04	67.77	72.30	72.43	63.25	68.94
S_2	66.50	72.10	71.82	62.30	68.18	67.72	73.79	73.40	63.48	69.60	68.53	74.82	74.48	64.10	70.48
S_3	65.21	68.25	68.64	61.17	65.82	66.50	69.76	70.15	62.30	67.18	67.32	70.68	71.08	62.96	68.01
S_4	66.82	75.60	72.26	62.95	69.41	68.20	77.82	74.08	64.08	71.05	69.03	78.96	75.12	64.72	71.96
S_5	65.44	69.42	69.28	61.29	66.36	66.68	70.96	70.83	62.45	67.73	67.56	72.03	71.80	63.09	68.62
S_6	66.13	71.36	71.20	61.76	67.61	67.45	73.10	72.86	62.88	69.07	68.29	74.20	73.80	63.54	69.96
S_7	66.59	70.12	70.69	62.57	67.49	67.88	71.89	72.26	63.76	68.95	68.74	72.82	73.30	64.53	69.85
S_8	57.62	58.65	58.79	54.10	57.29	58.35	59.48	59.66	54.68	58.04	58.77	59.93	60.12	54.89	58.43
Mean	65.00	69.39	69.06	60.95	66.10	66.22	71.01	70.58	62.03	67.46	67.00	71.97	71.52	62.64	68.28
	M	**S**	**M@S**	**S@M**		**M**	**S**	**M@S**	**S@M**		**M**	**S**	**M@S**	**S@M**	
SE(d)	0.3525	0.4732	0.9529	0.9464		0.3598	0.4831	0.9727	0.9661		0.3640	0.4891	0.9848	0.9782	
CD @ 5%	1.1219	0.9693	2.0998	1.9386	-	1.1450	0.9895	2.1435	1.9791	-	1.1584	1.0019	2.1698	2.0038	-
CD @ 1%	2.0593	1.3077	3.0348	2.6154		2.1019	1.3350	3.0979	2.6701		2.1263	1.3517	3.1357	2.7035	

Table 9. Effect of different water regimes and organic manures on relative water content (per cent) of noni leaves.

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	52.12	61.78	62.25	45.03	55.30	54.28	65.03	66.38	47.11	58.20	55.31	67.13	68.04	48.09	59.64
S_2	53.68	70.53	76.53	45.67	61.60	56.48	74.08	80.38	47.52	64.62	57.92	76.07	82.29	48.63	66.23
S_3	49.76	54.25	54.92	44.19	50.78	51.06	57.87	57.81	45.26	53.00	52.25	59.65	59.19	46.17	54.32
S_4	53.17	81.24	74.32	46.47	63.80	56.72	86.27	78.57	48.17	67.43	57.61	89.84	80.15	49.21	69.20
S_5	51.03	58.04	59.17	44.78	53.26	53.27	62.58	63.13	45.91	56.22	54.14	64.19	65.46	46.32	57.53
S_6	52.46	71.41	67.62	45.26	59.19	54.91	75.74	71.84	47.34	62.46	55.79	77.38	73.06	48.51	63.69
S_7	54.07	66.32	64.41	46.06	57.72	57.02	70.05	68.24	48.19	60.88	58.77	72.25	70.17	49.13	62.58
S_8	38.79	40.17	40.56	33.26	38.20	39.15	41.36	41.29	34.02	38.96	39.85	41.62	41.92	34.41	39.45
Mean	50.64	62.97	62.47	43.84	54.98	52.86	66.62	65.96	45.44	57.72	53.96	68.52	67.54	46.31	59.08
	M	**S**	**M@S**	**S@M**		**M**	**S**	**M@S**	**S@M**		**M**	**S**	**M@S**	**S@M**	
SE(d)	0.3219	0.3979	0.8110	0.7958	-	0.3355	0.4192	0.8529	0.8383	-	0.3428	0.4296	0.8737	0.8591	-
CD @ 5%	1.0243	0.8151	1.8062	1.6302		1.0677	0.8586	1.8969	1.7173		1.0910	0.8799	1.9423	1.7599	
CD @ 1%	1.8802	1.0997	2.6346	2.1994		1.9599	1.1584	2.7634	2.3169		2.0027	1.1872	2.8287	2.3743	

irrigation + 50% FYM + 50%VC (M_2S_4) has led to higher leaf area. This may due to continuous and uninterrupted judicious supply of water and nutrients. This finding was strengthened by previous research of Umesha et al. (2011). The plants maintain a turgid condition during the day time under drip irrigation as compared to check basin method of irrigation. There is a possibility of wide opening of stomata for longer period which might have resulted in high exchange of gases. Similarly, noni leaves might have remained turgid and produced more leaf surface. Thus, in turgor state helps in absorption of more sun light and solar radiation. It could have resulted in higher rate of photosynthesis and increased the photosynthetic capacity, which ultimately might have resulted production of leaf area and in turn the LTR (Kadam, 1990). The crops experienced period of water stress before each irrigation under check basin method irrigation due to the limited availability of moisture and nutrients for the roots to absorb. As results of that, there is reduction in leaf area and LTR.

The higher leaf area is as a result of maintenance of favorable soil moisture in the rhizosphere and effective absorption by plants. The optimum P uptake and greater P mobility through frequent or continuous low volume irrigation can maintain three dimensional distribution patterns of water and nutrients and provide improved conditions for growth, water and nutrient uptake (Gal and Dudley, 2003). Similarly the higher leaf area and LTR may be due to the optimum uptake of nutrients especially nitrogen, iron and magnesium from the soil resulted in higher chlorophyll content which might have enhanced the photosynthetic rate and production of more leaf area. Similarly, in ginger, farmyard manure influenced the length and breadth of leaf and it is in accordance with the present investigation (Khandkar and Nigam, 1996).

The inoculation of farmyard manure in the treatment would have increased the friability, promoted aggregation of soil and increased the level of humus, thereby increasing the microbial activity. This in turn would have enhanced the production of photosynthates due to efficient photosynthesis leading to accumulation of more carbohydrates. This may be responsible for increased leaf area and LTR. Furthermore, inoculation of the biofertilizer, *Azospirillum* would have increased the activity of root exudates which in turn might have accelerated the activity of beneficial microbes by higher nitrogen fixation and secretion of growth promoting substances as reported by Okon and Kapulnik (1986) which owed to the luxuriant vegetative growth that was reflected on improved leaf area.

Two specific physiological attributes indicating abiotic stress tolerance *viz*., CSI and RWC of leaves was found to be the highest in the treat-ment combination M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC). Koleyreas (1958),

Table 10. Effect of different water regimes and organic manures on noni fruit yield per hectare (tones).

Treatment	M_1	M_2	M_3	M_4	Mean
S_1	14.98	19.79	20.18	11.35	16.58
S_2	16.02	22.78	23.48	12.15	18.61
S_3	13.87	17.77	17.54	10.48	14.92
S_4	16.48	25.68	24.39	13.29	19.96
S_5	14.33	19.36	18.79	10.76	15.81
S_6	15.46	22.08	21.74	11.77	17.76
S_7	17.01	21.10	21.38	12.62	18.03
S_8	5.54	6.25	5.97	4.87	5.66
Mean	14.21	19.35	19.18	10.91	15.91
	M	**S**	**M@S**	**S@M**	
SE(d)	0.0442	0.0604	0.1214	0.1209	-
CD @ 5%	0.1407	0.1238	0.2670	0.2476	
CD @ 1%	0.2583	0.1670	0.3851	0.3341	

Murty and Majumder (1962) and Kilen and Andrew (1969) while working with pine, rice and corn respectively found significant correlations between CSI and drought tolerance. Sanandachari (1978) reported that, CSI appeared to be more reliable index to assess the drought resistance or tolerance capacity in sugarcane varieties. Todd and Webster (1965) and Alizada and Sultanov (1970) interpreted the RWC of leaves as an evidence of higher drought tolerance in crops. The leaves of drought tolerant cultivars show more turgidity than that of the susceptible, which was evident in grapevine (Barkousi et al., 1979) and brinjal (Panchalingam, 1983). RWC is considered as an important measure of plant water status since, it reflects on the metabolic activity of the tissues and lethal leaf water stress, particularly at hot summer (Flower and Ludlow, 1986). Sunflower cv. Ida when grown under water deficit conditions showed a reduction of 12% in relative water content (Izzo et al., 1992).

Reddy and Krishnasastry (1984) while analyzing the RWC of safflower under moisture stress, observed a drastic reduction in RWC of crops under stress. The increased RWC of M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) may also be due to reduced water loss, continued water availability and continued water uptake under trickle irrigation system. The treatment combination comprising 100% WRc through drip (irrigation + 50% FYM + 50% VC (M_2S_4) recorded the highest fruit yield. Better availability and utilization of nutrients and water may be the possible reason for the promotary effects. Roots can easily translocate absorbed water from the soil where available soil moisture content was optimum at 100% WRc through drip irrigation.

Required energy for water absorption was very less under this treatment and ultimately led to easy energy translocation to the reproductive parts. Application of farmyard manure and vermicompost had increased the soil organic matter content and improved the soil structure and biological activity.

This would have reduced the loss of nitrogen by increased cation and anion exchange capacities in soil thereby enhancing the fruit development and yield. Further, by improving the structure of the soil by more aggregation, water holding capacity and air permeability were increased.

These comprehensive changes in soil might have improved the fruit development and number in turn fruit yield. The neutral to mildly acidic pH will be of highly useful in potential utilization of available macro and micro nutrients, which chiefly interrupt the major plant physiological processes *viz.,* photosynthesis and partitioning of photosynthates from source to sink. This might have ultimately increased the yield of fruits. Further, more humic substances present in farmyard manure could have mobilized the reserve food materials to the sink through increased activity of hydrolysing and oxidising enzymes. This combined application of farmyard manure and vermicompost would have helped in better availability and utilization of nutrients. All these scavenging effects might have made quick mobilization and availability of nutrients, which would have aided better plant growth and development. This in turn could have assisted for higher fruit yield of noni. Presence of humic substances in farmyard manure improves the soil tilth as a result of favourable physical conditions of soil *viz.,* water holding capacity and aeration. This might have enhanced the yield of fruits.

Farmyard manure contains humic acid, fulvic acid and humin. These organic acids would have stimulated photosynthetic organelles namely chloroplast more particularly on number of grana. The higher photosynthetic activity would have enhanced the yield. Another reason which can be attributed may be the increase in cell wall permeability resulting in more entry of essential elements into plants, thereby activating photosynthetic apparatus giving rise to enhanced formation of carbohydrates and proteins. This inturn would have increased the photo-synthetic rate. The presence of humic substances in farmyard manure was the additional source of poly-phenols that might have acted as respiratory catalysts, which inturn increased the rate of respiration and metabolic activity of the noni plants. This might have triggered higher photosynthetic rate and inturn fruit yield. Farmyard manure may form chelates with organic compounds during decomposition that might have increased the availability of micronutrients to plants. These micronutrients may involve electron transport system in photosynthesis and respiration process, thereby resulting in enhanced photosynthetic rate (Srivastava, 1996).

As in any other plant, leaves of noni are chief functional photosynthetic units. For normal production, a noni crop needs sufficient number of leaves at different growth phases. In that situation sustaining leaf production in any crop depends again on water and nutrient availability. The results of the present study also revealed a positive association between total number of leaves produced and the yield of the crop which is maximum in the treatment M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC). Several studies indicated the positive influence on production of more number of leaves from planting to various crop growth phases due to the incorporation of organic manures along with biofertilizers (Vidhya, 2004). Greater accumulation of dry matter conferred greater ability to give higher yield. This was obviously due to vigorous growth of plant. The results of the present study indicated more number of leaves, increased the photosynthetic activity resulting in higher accumulation of carbohydrates. Relatively higher level of carbohydrates could have promoted the growth rate and inturn increased the fruit yield. This was in accordance with the result of Padmapriya (2004) and Vanilarasu (2011).

The increase in yield was due to the improved performance of all crop growth and yield attributing characters due to better availability of soil moisture and plant nutrients throughout the crop growth period under drip combined organic farming system. Drip irrigation maintains the soil moisture around the field capacity between two irrigation intervals. On the other hand, check basin method has high fluctuation of moisture between field capacity and permanent wilting point. This might have resulted in lower fruit yield in noni under conventional check basin method of irrigation. These results are in confirmation with the findings of Aladakatti et al. (2012) and Behera et al. (2012).

In this study, the low yield was obtained in the treatment M_4S_8 (check basin method of irrigation + no manure and no fertilizers) this might be probably due to the low availability moisture and nutrients resulting in production of less number of leaves ultimately less photosynthates which inturn reflects low yield. The check basin method of irrigation had high fluctuation of moisture between field capacity and permanent wilting point. Thus, this result to lower fruit yield. These results corroborate with the findings of Behera et al. (2012). The reduced moisture availability in M_4S_8 (check basin method of irrigation + no manure and no fertilizers) creates water stress condition. As water stress increases, CO_2 assimilation per unit leaf area decreases (Acevedo et al., 1971). When soil moisture stress intensifies, photosyn-thesis gets restricted to few hours and peak rate reduces. As a result biomass accumulations become slower (Suanez et al. 1989). This inhibition of CO_2 assimilation by water stress is closely linked to the extent of closure of stomata in the leaf. In addition to that, the metabolic capacity of the cells for photosynthesis is also reduced in general (Hsiao, 1993). Studies have indicated that electron transport and photophosphorylation may be inhibited as a result of reduction in cell water content (Leebot et al. 1998).

Conclusion

Water stress generate active oxygen species which are extremely reactive and cytotoxic and it can affect the respiratory activity in mitochondria, which can cause pigment break down and thereby less of carbon fixing capacity of chloroplasts (Scandalios, 1993). As result, there is reduction in fruit yield. The treatment combination of M_2S_4 (100% WRc through drip irrigation + 50% FYM + 50% VC) exhibited the highest yield through improved leaf area, light transmission ratio, chlorophyll stability index and relative water content.

ACKNOWLEDGEMENT

The authors express their gratitude to World Noni Research Foundation, Chennai, Tamil Nadu, India for providing financial support to carry out this research work.

Conflicts of interest

The authors have none to declare.

REFERENCES

Acevedo E, Hsiao TC, Henderson DW (1971). Immediate and subsequent growth responses of maize leaves to changes in water status. Plant Physiol. 48:631-636.

Aladakatti YR, Palled YB, Chetti MB, Halikatti SI, Alagundagi SC, Patil PL, Patil VC, Janawade AC (2012). Effect of irrigation schedule and planting geometry on growth and yield of stevia (*Stevia rebaudiana*

Bertoni.). Karnataka J. Agric. Sci. 25(1):30-35.

Alizada MA, Sultanov JH (1970). Changes in the concentration of cell sap and the water retaining capacity of the leaves of some wheat and barley varieties in relation to their drought resistance. Plant Breed. Abstr. 43:6672.

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.

Aref AB, Ray PM (1967). Regulation of cell wall synthesis in response to auxin in pea stems segments. Plant Physiol. 42:4.

Barkousi HE, Hifny AA, Baghadi GA (1979). Effects of water stress on some physiological aspects in grapevines (*Vitis vinifera*). Egypt. J. Hort. 6:91-103.

Barrs HD, Weatherly PE (1962). A re-examination of relative turgidity for estimating water deficits in leaves. J. Biol. Sci. 15(2):413-428.

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.

Flower DS, Ludlow MM (1986). Contribution of osmotic adjustment to the dehydration tolerance of water stressed pigeonpea (*Cajanus cajan* (L) Millap) leaves. Plant Cell Environ. 9:33-40.

Gal AB, Dudley LM (2003). Phosphorus availability under continuous point source irrigation. Soil Sci. Soc. Am. J. 67:1449-1456.

Galston AW, Dalberg LY (1954). The adaptive formation and physiological significant of indole acetic acid oxidase. Amer. J. Bot. 41: 373-389.

Hsiao TC (1993). Growth and productivity of crops in relation to water status. Acta Hort. 335:137-148.

Izzo NF, Sgherri LM, Izzo R, Quartacci K (1992). Proline accumulation related to water stress in sunflower seedlings subjected to drought. Agric. Mediterr.122(4):269-274.

Kadam JR (1990). Evaluation of soil, water, plant and atmospheric parameters in relation to furrow, sprinkler and drip irrigation methods for tomato in inceptisols. PhD Thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India.

Khandkar UR, Nigam KB (1996). Effect of farmyard manure and fertility level on growth and yield of ginger (*Zingiber officinale*). Indian J. Agric. Sci. 66(9):549-550.

Kilen TC, Andrew RH (1969). Measurement of drought resistance in corn. Agron. J. 61:669-671.

Koleyreas SA (1958). A new method for determining drought resistance. Plant Physiol. 33:232-233.

Leebot J, Adamowicz S, Robin P (1998). Modeling plant nutrition of horticultural crops. Sci. Hort. 74:477-482.

Mahadevan VC (1988). Effect of foliar nutrition of NPK on banana cv. Nendran (AAB). MSc Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

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.* Intl. J. Noni Res. 1(1):1-16.

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

Murty KS, Majumder SK (1962). Modification of the techniques for determination of chlorophyll stability index in relation to studies of drought resistance in rice. Curr. Sci. 31:470-471.

Okon Y, Kapulnik Y (1986). Development and function of *Azospirillum* inoculated roots. Plant Soil. 90:3-16.

Padmanabhan K (2003). Effect of organic manures on growth, root yield and alkaloid content of ashwagandha (*Withania somnifera* (L.) Dunal) ‘Jawahar’. MSc Theis, 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.

Panchalingam S (1983). Studies on drought tolerance in brinjal (*Solanum melongena* L). MSc Theis, 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.

Parthasarathy K, Balu RC, Rao PS (1970). Polyphenol oxidase activity and metabolism of sandal (*Santalum album*) in healthy and diseased plants. Proc. Indian Acad. Sci. 72:277-284.

Reddy VS, Krishnasastry KS (1984). Free proline accumulation and RWC under moisture stress in genotypes of safflower. Curr. Sci. 46(18):646-647.

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

Salki K (1963). The response of potato (*Solanum* spp.) to photoperiod and light intensity under high temperature. Potato Res. 31:73-83.

Sanandachari A (1978). Studies on factors influencing drought resistance in sugarcane varieties. Andhra Agric. J. 25:166-171.

Scandalios JG (1993). Oxygen stress and super oxide dismutase. Plant Physiol. 1010:7-12.