Indian J. Hort. 67(Special Issue), November 2010: 317-322

Effect of spacing and nitrogen on productivity and nitrogen use indices of colocynth under rainfed condition

R.N. Kumawat*, S.S. Mahajan and R.S. Mertia**
Regional Research Station, Central Arid Zone Research Institute, Jaisalmer 345001

ABSTRACT

An experiment on effect of intra row plant spacing and nitrogen nutrition on the yield attributes, yields, nutrient accumulation and nitrogen use efficiencies of colocynth (*Citrullus colocynthis*) was carried out during 2005 and 2006 under rainfed condition. The experiment consisted of 16 treatments with 4 intra–row plant spacings (50, 75, 100 and 150 cm) and 4 nitrogen levels (0, 20, 40 and 60 kg/ha). Plant spacing at 150 cm produced higher fruits/plant, average size and weight of fruits over closer plant spacings. The yields of plant dry matter, dry fruit, seed and oil per hectare recorded significantly the highest with 75 cm plant spacing. Nitrogen and phosphorus uptake (kg/ha) by the leaf, vine and total biomass was recorded maximum with 75 cm spacing while 100 cm spacing recorded maximum uptake in rind, pulp, cotyledon, testa and fruits. Successive increase in nitrogen levels up to 40 kg/ha recorded significantly higher yield parameters per plant and yields per hectare. The uptake of nitrogen and phosphorus in leaf and vine increased up to 60 kg N /ha while the maximum uptake of these nutrients in fruit (rind, pulp, cotyledon and testa) and total biomass was recorded with 40 kg N/ ha. Significantly higher values of agronomic nitrogen use efficiency (ANUE) and apparent nitrogen recovery (ANR) were recorded with 75 cm plant spacing and 20 kg N/ha due to higher fruit yields per unit area.

Key words: colocynth, nitrogen, spacing, yield attributes, yield, ANUE, and ANR

INTRODUCTION

About 60 percent arable farming of India falls under rainfed agriculture. The farmers of the area are generally resource poor and are not quite competitive within the country as compared to farmers of the well-endowed areas. However, there are some regional specific opportunities, which could be exploited in order to translate the weakness into opportunities and provide significant livelihood gains to the farmers of the region. In western Rajasthan adaptability of colocynth provides an excellent opportunity to supply food, oil and protein for human consumption, feed and fodder for live stock, and chemicals for agro-pesticide industries. The perennial vine grows naturally in the arid zones during monsoon and bears fleshy pepo from September to December. It has potential to produce 400-500 quintals of fruits a hectare during good rainfall years. Fresh fruit of colocynth weighing about 500 g has 74 percent of pulp which can be employed in preparation of preserve, candy, pickle and other confectionary items after suitable chemical treatment (Kumawat *et al.,* 4). On dry weight basis fruits contain 50 percent seeds rich in oil (26.5%) (Milovanovic and Picuric-Javanovic, 5) employed in soap making, automobiles and cooking. From nutrition point of view its oil has resemblance with safflower oil (Kumawat *et al.,* 3) and in some African and Middle Eastern countries it is being used for cooking (Milovanovic and Picuric-Javanovic, 5). The available evidences thus indicate its tremendous potentiality as an alternative crop for oilseeds. Being an underexploited crop, the cultivation practices of the crop have not been standardized yet. Among the cultural schedule for any crop, optimization of planting density and fertilizer management are considered most important (Singh and Chhonkar, 10). Competitive capacity of plant for nutrients, moisture and light entirely depends on intensity of plant population. An adequate supply of N is considered extremely important in determining the yield of a plant because of its role in the synthesis of protein, nucleic acid and many other vital cell constituents of the plants. In arid and semi-arid regions efficiencies of inorganic fertilizers are less than expected. Losses of applied nitrogen under such conditions are seldom less than 60-70% (Qadir *et al.,* 8) and efficiency of phosphorous is too low due to higher pH and $CaCO_3$ content of soil. Besides soil and climatic factors, management factors also influence fertilizer nitrogen recovery. Agronomic nitrogen use efficiency and physiological use efficiency

*Corresponding author's E-mail: rnkumawat@rediffmail.com
**Central Arid Zone Research Institute, Jodhpur

of applied fertilizer have been reported to be about 50% or less for nitrogen (Baligar *et al.* 1). The impact of both N rate and plant density on cultivated cucurbits has been reported in the literature frequently, yet there is insufficient knowledge about their impact on colocynth. Keeping this in view an experiment was carried out to study the effect of plant spacing and nitrogen levels on the productivity, nutrient accumulation (N and P) and N use efficiencies of colocynth grown under rainfed conditions.

MATERIALS AND METHODS

The experiment was conducted at Chandan Farm, CAZRI Regional Research Station, Jaisalmer, Rajasthan during *kharif* 2005 and 2006. The soils of the experimental site was sandy with $CaCO_3$ concretions below 50 cm, having 0.08% organic carbon, 72.80 kg/ha available N, 6.45 kg/ha P and 215.78 kg/ha K with pH 9.2. Four intra – row plant spacings (50, 75, 100 and 150 cm) were assigned to the main plots and 4 nitrogen levels (0, 20, 40 and 60 kg/ha) to the sub-plots in a split plot design having 3 replications. The rows were 2.5 m apart in all the treatments and there were four rows in each of the sixteen treatments. A uniform dose of 40 kg P_2O_5 /ha was applied through single super phosphate as fertilizer in all the treatments. Nitrogen as per the treatment was supplied through urea (46 % N) at the time of sowing.

The seeds of the colocynth sown manually at the onset of monsoon on 4th August 2005 by placing three seeds per hole at a depth of 5 cm and plants were thinned to one per stand 10 days after emergence. The second year study was conducted on the ratoons of the previous year sowing. Two plants per treatment were taken for dry matter production and yield by cutting the vines at soil surface level. Each sample was separated into its component plant parts – leaves, stems and fruits – and oven dried to calculate dry matter partitioning. The average size and weight per fruit were calculated from five randomly selected fruit from each treatment. The fruits were peeled off manually with the help of sharp knife and dried in hot air oven at 60°C for 72 hours to determine weight and proportion of rind, pulp and seed to total fruit weight. Twenty seeds from each treatment were decoated manually for determination of testa and cotyledon proportion to total seed

The over night dried (50°C) seeds of the colocynth were ground into powder in a Mortar-Pestle for determination of oil. Five grams of powder were mixed with 100 ml petroleum ether (40-60°C) and the oil fraction was extracted in a Soxhlet apparatus for 16 h at 60°C. The solvent was evaporated and the oil fraction was weighed (Yaniv *et al.,* 14). Oven dried (65° C for 48 hours) ground samples of leaf, vine, rind, pulp, testa and cotyledon were analyzed for N and P content (Jackson, 2). The various nitrogen use efficiencies were computed with the formulae given below:

Agronomic N use efficiency (ANUE) = (Fruit yield in the test treatment, kg/ha - Fruit yield in the control, kg/ha) / Units of nutrient applied in the test treatment, kg/ha

Physiological N use efficiency (PNUE) = (Fruit yield in the test treatment, kg/ha - Fruit yield in the control, kg/ha) / (Uptake of N in the test treatment, kg/ha – Uptake of N in the control plot, kg/ha)

Apparent N recovery (ANR) (%) = 100 x (Uptake of N in the test treatment, kg/ha – Uptake of N in the control plot, kg/ha) / N applied to the test treatment, kg/ha

N efficiency ratio (NER) = Dry matter yield (kg/ha) / N accumulated at harvest (kg/ha)

Physiological efficiency index of N (PEN) = Fruit yield (kg/ha) / N absorbed by biomass (kg/ha)

N harvest index (NHI) (%) = (N uptake by the fruit at harvest, kg/ha / N uptake by the whole plant at harvest, kg/ha) x 100

All the data recorded in the experiment were subjected to computer analysis using split plot design software (SPSS version 13.0).

RESULTS AND DISCUSSIONS

The number of fruits per plant at harvest varied from 4.8 to 10.4 fruits within the intra row spacing, with spacing 150 cm having significantly the highest (Table 1). Similarly, average size and weight of fruits increased linearly with successive increase in plant spacing. The 100–seed weight did not influence statistically with the increased plant spacing from 50 to 150 cm. Although oil content among 75, 100 and 150 cm spacing found non significant with each other, intra row plant spacing at 100 cm recorded 3% higher oil content in the seeds compared to control (25.0 %). The total dry matter production, dry fruits, seeds and oil yields per hectare increased significantly with the increase in intra row plant spacing only up to 75 cm. Colocynth plants planted with a plant spacing of 75 cm had 15.8, 13.8 and 16.1% higher dry fruit, seed and oil yields per hectare compared to 50 cm plant spacing, respectively. The increased weight and size of the fruits with increased plant spacing might be associated with increased crop growth. Since dry matter accumulation per plant showed consistent increase under wider spacing in comparison to the plants sown at closer spacing. Further, in the study fruits per plant is positively correlated (r=0.92) with the number of leaves per plant. Thus, fruits per plant decreased in closer spacing owing to reduced leaf area per plant. Similarly, Watanabe *et al.* (13) in water melon observed that lower plant spacing significantly correlated with lower total leaf

Table 1. Effect of various spacing and nitrogen levels on yield attributes and yields of colocynth, mean of *kharif* 2005 and 2006 seasons.

Treatments	Yield attributes						Yield			
	No. of fruits/ plant	Average size of fruit (cm)	Average fruit wt. (g)	100 seed wt. (g)	No. of seeds/ fruit	Oil content (%)	Plant dry matter (kg/ha)	Dry fruit yield (kg/ha)	Seed yield (kg/ha)	Oil yield (kg/ha)
Spacing, cm										
S_{50}	4.76	7.78	29.56	3.05	438.20	25.04	1886.08	905.48	384.53	96.01
S_{75}	7.60	8.46	31.54	3.09	515.62	25.62	2173.00	1048.14	437.75	111.46
S_{100}	9.29	8.75	34.19	3.12	520.37	25.80	2018.23	1044.14	435.20	111.84
S_{150}	10.41	9.08	34.85	3.12	538.26	25.98	1494.47	792.26	305.04	78.65
CD at 5%	0.65	0.32	1.54	NS	22.25	0.61	91.79	59.37	21.22	4.85
Nitrogen, kg ha^{-1}										
N_0	7.76	8.20	21.38	2.98	459.40	26.72	1388.40	590.22	263.95	70.54
N_{20}	8.00	8.42	32.64	3.02	475.77	25.98	1863.81	942.24	402.36	104.54
N_{40}	8.44	8.66	40.87	3.27	531.30	25.06	2251.02	1255.98	509.35	127.54
N_{60}	7.85	8.77	35.26	3.11	545.97	24.68	2068.54	1001.58	386.85	95.35
CD at 5%	0.50	0.30	1.12	0.15	25.67	0.34	86.11	43.20	19.78	4.97

area per plant, plant dry weight and fever fruits per plant. The seeds per fruit were significantly higher with widest plant spacing owing to bigger size of the fruits compared to other plant spacing and hence more seeds per fruit can be expected in the study. Analogous results were also reported by Ogbonna and Obi (7) in *Citrullus colocynthis*. The higher oil content of the seeds with increasing spacing in the study attributed to increased proportion of cotyledon with concurrent decreased proportion of the testa. Because in cucurbits growth of testa terminates earlier than the cotyledon and sufficient supply of growth inputs with increased spacing help development of the cotyledon (Nerson, 6). The higher proportion of the cotyledon might have increased the oil content of the seeds. Though per plant dry matter and yield attributes increased linearly with the increase of plant spacing, the dry matter yield, dry fruit, seed and oil yield per unit area was higher under 75 cm planting spacing. This was due to higher plant population per unit area under 75 cm spacing compared to 100 and 150 cm. The wider plant spacings in the study failed to compensate the loss incurred due to less population while 50 cm plant spacing produced lesser fruits per plant and thereby low seed and oil yield. Similar findings were also reported by Singh & Chhonkar (10) in musk melon.

From the results it is evident that fruits per plant, average fruit weight and 100-seeds weight were significantly increased from 7.8 to 8.4, 21.4 to 40.9 g and 3.0 to 3.3 g with increased nitrogen levels from 0 to 40 kg/ha (Table 1). Similarly, plant dry matter per hectare increased from 1388 to 2251 kg, dry fruit yield 590 to 1256, seed yield 264 to 509 and oil yield 71 to 128 kg with 0 to 40 kg N/ha. Further increase of nitrogen level recorded lesser seed and oil yields. The average fruit size and number of seeds per fruit increased significantly up to 60 kg N/ha. The oil content in seeds however, decreased from 26.7 to 24.7% with the increase in nitrogen levels from 0 to 60 kg/ha. The significant improvement in the fruits per plant, average size and weight of fruit with successive increase in N level up to 40 kg/ha in the study might be associated with increased physiological and biochemical parameters of the plant. Further increase in nitrogen level decreased number of fruits per plant due to shift of sex ratio in favour of staminate flowers (Robinson and Decker–Walters, 9). The significant decrease in fruit weight with 60 kg N could be attributed to lower proportion of seeds and higher proportion of pulp in the fruits compared to 40 kg N. The bigger size fruit with higher nitrogen levels in the study resulted in higher 100 seed weight and more number of seeds per fruit compared to no N. The increasing nitrogen levels in the study decreased the oil content of the seeds because of increased concentration of crude protein in the seeds. Further, the proportion of testa to total seed weight increased with successive increase in the nitrogen levels from 0 to 60 kg/ha in the study. The decreased proportion of the cotyledon might have decreased the concentration of oil in the seeds with increasing nitrogen levels. At the harvest of plant, fruits contributed more than 50 percent in the total biomass of the plant. The decreased number of fruits per plant with 60 kg N/ha probably decreased the total dry matter yield per unit area compared to 40 kg N and thereby lower fruit, seed

Table 2. Effect of various spacing and nitrogen levels on N and P uptake of colocynth at harvest, mean of kharif 2005 and 2006 seasons.

Treatments	N uptake (kg/ha)							P uptake (kg/ha)						
	Leaf	Vine	Rind	Pulp	Cotyledon	Testa	Total	Leaf	Vine	Rind	Pulp	Cotyledon	Testa	Total
Spacing, cm														
S_{50}	2.58	4.21	0.78	0.85	4.77	1.42	14.60	1.26	2.29	0.50	0.50	1.88	0.91	7.35
S_{75}	3.30	5.19	0.99	1.08	5.67	1.63	17.86	1.58	2.81	0.67	0.64	2.33	1.17	9.20
S_{100}	3.17	4.53	1.04	1.21	6.03	1.70	17.69	1.46	2.53	0.69	0.71	2.53	1.20	9.13
S_{150}	2.57	3.38	0.90	1.11	4.81	1.24	14.02	1.18	2.08	0.58	0.69	1.94	0.87	7.34
CD at 5%	0.23	0.32	0.03	0.04	0.18	0.05	0.91	0.10	0.13	0.02	0.03	0.07	0.04	0.46
Nitrogen, kg/ha														
N_0	2.05	3.49	0.46	0.49	3.77	0.89	11.15	1.00	1.86	0.34	0.29	1.43	0.56	5.47
N_{20}	2.74	4.18	0.86	0.99	5.58	1.49	15.84	1.31	2.34	0.58	0.59	2.23	0.95	8.01
N_{40}	3.19	4.61	1.32	1.47	6.89	2.01	19.51	1.51	2.67	0.84	0.87	2.89	1.34	10.13
N_{60}	3.64	5.02	1.07	1.30	5.04	1.60	17.67	1.66	2.85	0.68	0.79	2.12	1.31	9.41
CD at 5%	0.18	0.30	0.03	0.04	0.17	0.05	0.84	0.08	0.13	0.02	0.03	0.07	0.04	0.42

and oil yield. Analogous study was also reported by Singh and Naik (11) in *Citrullus lanatus*.

Nutrient accumulation in plants is a function of nutrient concentration and dry matter accumulation. Successive increase in plant spacing from 50 to 150 cm had a highly significant effect on the accumulation of nitrogen and phosphorus in the leaf, vine, rind, pulp, cotyledon, testa and total biomass (kg/ha). Intra row spacing at 75 cm recorded significantly higher nitrogen and phosphorus accumulation in leaf, vine and total biomass than rest of the spacings (Table 2) because of higher leaf, vine and total biomass yields per unit area with 75 cm spacing. However, 100 cm spacing recorded statistically higher uptake of nitrogen and phosphorus in fruit (rind, pulp, cotyledon and testa) due to higher content of nutrients in these plant parts compared to 50 and 75 spacing.

Nitrogen nutrition had a significant effect on the nitrogen and phosphorus accumulation of the crop (Table 2). With each increment in the nitrogen level there was a significant increase in nitrogen and phosphorus accumulation of the leaf and vine up to 60 kg N /ha, while maximum uptake of these nutrients in fruit (rind, pulp, cotyledon and testa) and total biomass was recorded with 40 kg N/ ha. The higher uptake of nitrogen and phosphorus in leaf and vine with 60 kg N/ha is attributed to higher content of these nutrients in leaf and vine plant parts due to increased root ramification with least competition. Application of nitrogen beyond 40 kg/ ha decreased number of fruits per plant owing to shift of sex ratio in favour of staminate flowers (Robinson and Decker–Walters, 9) and thus lower fruit yield with 60 kg N /ha. Besides, Wan *et al*. (12) reported that in *Citrullus lanatus* N, P, and K nutrients were absorbed at very low rate during the seedling stage and gradually increased with the progress of crop growth and after fruit setting maximum amounts of nutrients were accumulated in the fruits. In the study fruits contributed more than 50 percent in the total biomass of the plant at harvest and maximum fruit yield was obtained with 40 kg N/ha. Hence in the study higher uptake of nitrogen and phosphorus with 40 kg N /ha is the result of higher dry matter of fruits and total biomass compare to rest of the nitrogen levels.

Various nitrogen use indices differed considerably with successive increase in intra-row plant spacing (Table 3). Significantly higher values of ANUE and ANR were recorded with 75 cm plant spacing due to higher fruit yields per unit area than the other spacings. PNUE and NHI were recorded significantly maximum with 150 cm spacing is attributed to lower fruit yield and uptake of nitrogen because of reduced plant population per unit area. In the study lower nitrogen content and uptake of nitrogen in different plant parts compared to higher dry

Table 3. Effect of various spacing and nitrogen levels on ANUE (kg fruit / kg N), PNUE (kg fruit / kg N uptake), ANR (%), NER (kg DM / kg N uptake), PEN (kg fruit / kg N uptake) and NHI (%) of colocynth, mean of *kharif* 2005 and 2006 seasons.

Treatments	ANUE	PNUE	ANR	NER	PEN	NHI
Spacing, cm						
S_{50}	10.55	61.99	12.82	129.95	61.22	53.02
S_{75}	12.11	52.79	16.89	123.10	58.37	52.00
S_{100}	9.60	44.84	13.50	114.75	58.89	56.19
S_{150}	8.85	72.99	12.03	109.06	57.61	57.41
CD at 5 %	0.56	4.94	1.27	5.96	NS	3.16
Nitrogen, kg/ha						
N_0	0.00	0.00	0.00	124.61	52.98	50.27
N_{20}	17.60	75.66	23.48	117.69	59.63	56.44
N_{40}	16.64	96.51	20.89	117.30	66.29	60.61
N_{60}	6.86	60.44	10.87	117.27	57.19	51.30
CD at 5 %	0.51	4.53	1.16	5.47	4.32	2.88

ANUE = agronomic nitrogen efficiency; PNUE = physiological nitrogen use efficiency; ANR = apparent nitrogen recovery; NER = nitrogen efficiency ration; PEN = physiological efficiency index of nitrogen and NHI = nitrogen harvest index; NS = non-significant

matter accumulation result into highest NER with 50 cm than rest of the spacing. The various plant spacings did not affect PEN statistically.

Application of nitrogen at 20 kg/ha recorded significantly the highest ANUE and ANR due to higher fruit yields per unit nitrogen than the other nitrogen levels (Table 3). The increment in nitrogen levels beyond 20 kg/ha reduced these indices considerably. However, application of 40 kg N/ha recorded significantly higher PNUE, PEN and NHI than other nitrogen levels. The higher value of these indices with 40 kg N/ha might be associated with higher uptake of nitrogen per unit of area than other treatments because of better nutritional environment both in plant and rhizosphere. The highest value of NER with 0 kg N/ha could be attributed to lower content and uptake of nitrogen compared to higher dry matter production per unit of area.

REFERENCES

1. Baligar, V.C., Fageria, N.K. and He, Z.L. 2001. Nutrient use efficiency in plants. In: *Annl. Conference of the Soil and Water Conservation Society.* August 8-11, 1999 Mississippi, **32**: 921-50.
2. Jackson, M. L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Private Limited, New Delhi, India.
3. Kumawat, R.N., Mahajan, S.S. and Mertia, R.S. 2009. Effect of intra-row spacing and nitrogen on yield and yield attributes of colocynth (*Citrullus colocynthis*) under rainfed conditions. *Indian J. Agri. Sci.* **79**: 298-301.
4. Kumawat, R.N., Mahajan, S.S., Mertia, R.S. and Prajapati, C.P. 2006. *Citrullus colocynthis*- – A marvel herb for botanicals and food products from Desert flora. In: *Botanical Products – Innovation, Challenges, Problems, Solutions and Trans-national Marketing. Proc. Intl. Symp*. 5-7 February, 2006, Department of Chemistry, University of Rajasthan, Jaipur, India, pp. 60-62.
5. Milovanovic, M. and Picuric-Jovanovic, K. 2005. Characteristic and composition of melon seed oil. *Journal Agril. Sci*. Belgrade **50**: 41-47.
6. Nerson, H. 2007. Seed production and germinability of cucurbit crops. *Seed Sci. Biotec*. **1**: 1-10.
7. Ogbonna, P.E. and Obi, I.U. 2000. The influence of poultry manure application and plant density on the growth and yield of egusi melon (*Colocynthis citrullus*) on the Nsukka plains of South Eastern Nigeria. *Agro Sci. J. Trop. Agric. Food Environ. Exten.* **1**: 122-29.
8. Qadir M, Noble A D, Schubert S, Thomas R J and Arslan A. 2006. Sodicity-induced land degradation and its sustainable management: Problems and prospects. *Land Degrad. Develop.* **17**: 661–76.
9. Robinson, R.W. and Decker–Walters, D.S. 2004. *Cucurbits*. CABI: Cambridge University Press, UK,

p. 18.

10. Singh, D.N. and Chhonkar, V.S. 1986. Effect of nitrogen, phosphorus, potassium and spacing on growth and yield of musk melon (*cucumis melo* L.). *Indian J. Hort.* **43**: 265-69.

11. Singh, R.V. and Naik, L.B. 1989. Response of water melon (*Citrullus lanatus* Thumb. Monsf.) to plant density, nitrogen and phosphorus fertilization. *Indian J. Hort.* **46**: 80-83.

12. Wan, L.Q., Xiang, W.L., Guo, L.Z., Ping, L.S., Xiang, Q.J. and Yan, T.H. 2006. Absorption and distribution of nitrogen, phosphorus and potassium in mini water melon in different growth stages. *South-west China J. Agril. Sci*. **19**: 838-41.

13. Watanabe, S., Nakano, Y. and Okano, K. 2001. Relationship between total leaf area and fruit weight in vertically and horizontally trained water melon (*Citrullus lanatus* Thumb.) plants. *J. Japanese Soc. Hort. Sci*. **70**: 725-32.

14. Yaniv, Z., Elber, Y., Zur, M. and Schafferman, D. 1991. Differences in fatty acid composition of oils of wild Cruciferae seeds. *Phytochem.* **30**: 841-843.

Received: July, 2008; Revised: February, 2010
Accepted: August, 2010