



Effect of spacing and nitrogen levels on growth, flowering, yield and quality of garden rue (*Ruta graveolens* L.)

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Abstract: At harvest (180 DAP), maximum plant height, fresh and dry herbage and root yield per plot, per hectare and oil yield per hectare was noticed in S₁ (45 x 30 cm). Minimum days to first flowering was observed with spacing of 45 x 45 cm (S₂) whereas, wider spacing of 45 x 60 cm (S₃) registered more number of primary branches per plant, flowers per plant, maximum plant spread, stem girth, fresh and dry herbage and root yield per plant and per cent dry matter. At harvest, application of 150 kg nitrogen per hectare (N₁) recorded maximum plant height, more number of primary branches per plant, flowers per plant, plant spread, stem girth, fresh and dry herbage and root yield per plant, per plot, per hectare and per cent dry matter. Minimum days to first and fifty per cent flowering was noticed with application of 60 kg nitrogen per hectare (N₁). Whereas, highest essential oil content, oil yield per plant and per hectare was observed with the application of 120 kg nitrogen per hectare (N₃). At harvest, the treatment combination S₃N₄ recorded highest fresh and dry herbage yield per plant, whereas highest fresh root yield per plant was recorded in S₂N₄. Plants grown at S₁N₄ combination registered maximum plant height, fresh and dry herbage and root yield per plot, per hectare, oil yield per hectare, per cent dry matter.

Key words: Garden rue, Spacing, Nitrogen levels, Growth, Yield and Quality.

Introduction

The Rutaceae family comprises of extremely wide variety of medicinal plants, mainly distributed in tropical regions. A wide variety of plants of the family Rutaceae are used in traditional system of medicine world-wide. The most common medicinal plant of this family is Garden Rue (*Ruta graveolens* L.) which is used since times immemorial in Ethanobotany. It is cultivated as a medicinal herb, as a condiment, and to a lesser extent as an insect repellent. Aerial parts of the herb are used as economic part. Rue contains more than 120 natural compounds mainly including acridone alkaloids, coumarines, essential oils (0.5%), flavonoids (Rutin) and furoquinolines (1.4%) found in the roots and aerial parts of this plant and is the main source of furanocoumarins such as psoralen and bergapten (5-methoxypsoralen; 5-MOP) which are valued in pharmaceutical industry. The compound responsible for the bitter taste is Rutin (7 to 8% in the dried leaves).

It has been used internally as an antispasmodic, as a treatment for menstrual problems, as an abortifacient, and as a sedative. The whole herb is anthelmintic, antidote, carminative, emetic, emmenagogue, expectorant, haemostatic, ophthalmic, rubefacient, strongly stimulant, mildly stomachic and uterotonic. Ruta in combination with calcium phosphate [Ca₃(PO₄)₂] could be used as effective treatment for brain cancers, particularly glioma (Pathak *et al.*, 2003). Spacing is an important factor which can limit crop growth and yield. The factors, viz., dry matter accumulation, nutrient uptake, flower number and herb yield are dependent on optimum spacing level. Hence, there is a need to determine specific spacing

for crop production. Nitrogen is an important component of enzymes and nucleic acids. It is an integral constituent of chlorophyll, which promotes photosynthesis and formation of photosynthates from which the vegetative parts are developed. These vegetative structures have a direct bearing on yield (Kanwar, 1978). It is possible to produce higher yields by judicious practices in the supply of nutrients and adoption of proper spacing. Being an herbaceous crop, great potential exists for increasing the plant growth, yield and quality through the application of inorganic nitrogenous fertilizers. With this objective the present study was conducted to evaluate the effect of spacing and nitrogen levels on growth, flowering, yield, quality and economics of Garden rue (*Ruta graveolens* L.).

Materials and Methods

Field experiment was conducted at the department during 2012 to 2013. This experiment was laid out in factorial randomized block design (FRBD) with twelve treatments and three replications. The treatments consisted of two factors viz., factor1; Spacing with three levels (45 x 30 cm, 45 x 45 cm and 45 x 60 cm) and factor2; Nitrogen with four levels (60, 90, 120 and 150 kg / ha). The size of the experimental plot was 3.0 m x 1.8 m with different spacing levels. Well decomposed FYM was applied 15 days before transplanting, at the rate of 10 ton per hectare and mixed thoroughly into the soil. The treatments were allocated to individual plots at random. Spacing was adopted in each plot as per the treatment allocation. The nutrients were applied in the form of straight fertilizers with Nitrogen in the form of urea, Phosphorous in the form of Single Super Phosphate and Potassium in the form of Muriate of Potash.

The seedlings were raised from seeds in two nursery beds of 15 cm height, 1 m width and 2.5 m length. Fifty days old, healthy and uniform sized seedlings were selected and transplanted in the experimental plots as per the treatments.

The fertilizer mixture was applied by broadcasting uniformly in rows to individual plots as per the treatment and mixed thoroughly in to the soil. Out of total quantity, half dose of nitrogen and full dose of phosphorous (30 kg / ha) and potash (30 kg / ha) were supplied as basal dose one day before transplanting. The remaining half quantity of nitrogen was given as top dressing at 45 days after transplanting. The plots were kept weed free by hand weeding. The first irrigation was given immediately after transplanting and irrigated once in a week or fifteen days during the whole cropping period. The crop was harvested five months after transplanting at full flowering stage as it contains maximum percentage of active principles at this stage. Harvested herb was cut into pieces of convenient length along with flowers and immature capsules. This material was dried under partial shade for few hours and used for essential oil extraction. Essential oil is extracted by hydrodistillation method in the Clevenger's apparatus by adopting standard procedure and expressed in percentage on w/w basis. Observations were recorded on plant height, number of primary branches, plant spread, stem girth at harvest stage. Flowering parameters like number of flowers and days to first and fifty per cent

Table-1: Effect of spacing and nitrogen levels on plant height, number of primary branches, stem girth and days to first flowering in Garden Rue

Treatment	Plant ht. (cm)	No. of primary branches	Stem girth (mm)	Days to first flowering
Spacing level (S)				
S ₁ : 45 x 30 cm	45.42	10.31	11.62	122.42
S ₂ : 45 x 45 cm	43.48	10.74	12.07	120.00
S ₃ : 45 x 60 cm	42.57	11.64	12.96	126.67
S.Em±	0.63	0.28	0.22	1.49
CD @ 5 %	1.87	0.83	0.66	4.37
Nitrogen level (N)				
N ₁ : 60 kg N / ha	41.08	9.82	11.18	114.22
N ₂ : 90 kg N / ha	41.88	10.50	11.67	123.44
N ₃ : 120 kg N / ha	44.98	11.12	12.30	124.11
N ₄ : 150 kg N / ha	47.35	12.14	13.71	130.33
S.Em±	0.73	0.33	0.26	1.72
CD @ 5 %	2.16	0.96	0.77	5.04
Interaction (S x N)				
S ₁ N ₁	43.33	9.47	10.75	112.33
S ₁ N ₂	40.76	9.97	10.86	120.00
S ₁ N ₃	47.11	10.03	11.50	127.67
S ₁ N ₄	50.50	11.77	13.37	129.67
S ₂ N ₁	38.93	9.12	11.10	111.33
S ₂ N ₂	41.96	10.80	11.66	121.67
S ₂ N ₃	44.65	11.20	12.37	116.33
S ₂ N ₄	48.36	11.83	13.14	130.67
S ₃ N ₁	40.98	10.87	11.69	119.00
S ₃ N ₂	42.92	10.73	12.49	128.67
S ₃ N ₃	43.17	12.13	13.04	128.33
S ₃ N ₄	43.20	12.83	14.64	130.67
S.Em±	1.27	0.57	0.45	2.98
CD at 5 %	3.74	NS	NS	NS
CV (%)	5.05	9.09	6.46	5.19

flowering were also recorded at flowering stage. Yield characters like per cent dry matter, fresh and dry herbage and root yield per plant, plot and hectare were recorded. Quality parameters like Essential oil content, oil yield per plant and per hectare were recorded.

Results and Discussions

Experimental results indicated in (Table-1) showed that the highest plant height of 45.42 cm was recorded in S₁ (45 x 30 cm) and minimum plant height 42.57 cm was in S₃ (45 x 60 cm). Among the nitrogen levels used the 150 kg N / ha (N₄) recorded higher values for plant height 47.35 cm and minimum 41.08 cm was in N₁ (60 kg N / ha). Plant height showed significant variation among the interaction. The treatment combination of closer spacing level (45 x 30 cm) and higher nitrogen levels N₄ (150 kg N / ha) registered higher plant height (50.50 cm) and found to be on par with S₂N₄ (48.36 cm) and S₁N₃ (47.11 cm) which was superior over other treatment combinations. Plant height was found lower (38.93 cm) in S₂N₁ treatment combination. It has been well documented that the plant height increases with an increase in plant density as reported by Sherbeny *et al.* (2007) in garden rue. Significantly higher number of primary branches per plant 11.64 was noticed in 45 x 60 cm (S₃) spacing and minimum 10.31 in 45 x 30 cm (S₁). The higher number of primary branches per plant 12.14 and lower 9.82 was recorded in plants supplied with 150 kg N / ha (N₄) and 60 kg N / ha (N₁)

Table-2: Effect of spacing and nitrogen levels on days to fifty percent flowering, number of flowers per plant and plant spread in Garden Rue

Treatment	Days to 50% flowering	No. of flowers per plant	Plant spread {N-S(cm)}	Plant spread {E-W(cm)}
Spacing level (S)				
S ₁ : 45 x 30 cm	141.08	536.92	43.15	46.09
S ₂ : 45 x 45 cm	140.08	545.83	44.80	47.01
S ₃ : 45 x 60 cm	143.58	552.92	45.76	48.91
S.Em±	2.06	2.58	0.66	0.72
CD @ 5 %	NS	7.57	1.93	2.13
Nitrogen level (N)				
N ₁ : 60 kg N / ha	133.44	520.33	41.94	43.02
N ₂ : 90 kg N / ha	141.78	541.78	42.42	45.25
N ₃ : 120 kg N / ha	144.00	546.56	45.83	47.97
N ₄ : 150 kg N / ha	147.11	572.22	48.10	53.11
S.Em±	2.38	2.98	0.76	0.84
CD @ 5 %	6.98	8.75	2.23	2.46
Interaction (S x N)				
S ₁ N ₁	129.33	511.67	40.44	41.74
S ₁ N ₂	142.00	530.00	40.88	44.78
S ₁ N ₃	144.33	538.33	44.22	48.01
S ₁ N ₄	148.67	567.67	47.07	49.85
S ₂ N ₁	133.00	522.67	41.91	42.00
S ₂ N ₂	143.67	544.67	43.30	44.93
S ₂ N ₃	143.00	542.67	45.79	47.37
S ₂ N ₄	140.67	573.33	48.19	53.74
S ₃ N ₁	138.00	526.67	43.47	45.33
S ₃ N ₂	139.67	550.67	43.07	46.03
S ₃ N ₃	144.67	558.67	47.47	48.52
S ₃ N ₄	152.00	575.67	49.04	55.75
S.Em±	4.12	5.16	1.32	1.45
CD at 5 %	NS	NS	NS	NS
CV (%)	5.04	5.64	5.13	5.33

Table-3: Effect of spacing and nitrogen levels on fresh herbage yield, dry herbage yield and fresh root yield of Garden Rue

Treatment	Fresh herbage yield Per hec. (t)	Dry herbage yield Per hec.(t)	Fresh root yield Per hec.(t)
Spacing level (S)			
S ₁ : 45 x 30 cm	16.00	3.63	2.06
S ₂ : 45 x 45 cm	14.06	3.31	1.85
S ₃ : 45 x 60 cm	12.53	2.72	1.76
S.Em±	0.27	0.07	0.05
CD @ 5 %	0.80	0.21	0.16
Nitrogen level (N)			
N ₁ : 60 kg N / ha	13.16	2.99	1.77
N ₂ : 90 kg N / ha	13.57	3.17	1.83
N ₃ : 120 kg N / ha	14.51	3.22	1.88
N ₄ : 150 kg N / ha	15.54	3.49	2.09
S.Em±	0.31	0.08	0.06
CD @ 5 %	0.92	0.24	0.19
Interaction (S x N)			
S ₁ N ₁	14.52	3.43	1.83
S ₁ N ₂	14.77	3.46	1.95
S ₁ N ₃	17.31	3.45	2.13
S ₁ N ₄	17.40	4.16	2.34
S ₂ N ₁	13.74	3.01	1.87
S ₂ N ₂	14.62	3.58	1.77
S ₂ N ₃	15.25	3.53	1.97
S ₂ N ₄	12.62	2.55	1.80
S ₃ N ₁	11.22	2.52	1.61
S ₃ N ₂	11.31	2.47	1.77
S ₃ N ₃	10.98	2.12	1.53
S ₃ N ₄	16.59	3.77	2.13
S.Em±	0.54	0.14	0.11
CD at 5 %	1.61	0.43	0.33
CV (%)	6.70	7.92	10.58

respectively. Number of primary branches per plant did not differ significantly at any stages of plant growth due to interaction of spacing and nitrogen (Table-1). The increase in branching could be attributed to the availability of more spatial area for spreading which helped in more interception of light due to higher surface area and the results obtained were in similar to Pushpalatha *et al.* (2003) and Ameen *et al.* (1998). Stem girth was recorded highest (12.96 mm) in S₃ (45 x 60 cm) and lowest (11.62 mm) was found in S₁ (45 x 30 cm). Plants supplied with higher dose of nitrogen 150 kg / ha (N₄) resulted in higher stem girth (13.71 mm) and lowest (11.18 mm) was noticed with the application of 60 kg nitrogen per hectare (N₁). The combination of 45 x 60 cm spacing with 150 kg nitrogen per hectare (S₃N₄) recorded maximum (14.64 mm) stem girth while minimum stem girth of (10.75 mm) S₁N₁ treatment combination (Table-1). The results were in comparison with that of Subbireddy *et al.* (1991).

Days to first flowering was significantly influenced by different spacing levels. Among spacing levels, S₂ (45 x 45 cm) has shown early flowering by recording minimum days to first flowering (120 days) which was found to be on par with S₁ (122.42 days) while delayed flowering (126.67 days) was noticed in treatment S₃ (45 x 60 cm). Nitrogen levels had a significant effect on days to first flowering which ranged between 114.22 to 130.33 days. Plants

Table-4: Effect of spacing and nitrogen levels on essential oil content, oil yield and percent dry matter of Garden Rue

Treatment	Essential oil content (%)	Essential oil yield per hectare (kg)	Percent dry matter
Spacing level (S)			
S ₁ : 45 x 30 cm	0.19	28.76	21.49
S ₂ : 45 x 45 cm	0.18	25.74	22.75
S ₃ : 45 x 60 cm	0.19	25.36	23.85
S.Em±	0.004	0.57	0.33
CD @ 5 %	NS	1.68	0.97
Nitrogen level (N)			
N ₁ : 60 kg N / ha	0.18	26.92	21.55
N ₂ : 90 kg N / ha	0.17	24.77	21.91
N ₃ : 120 kg N / ha	0.21	27.67	22.69
N ₄ : 150 kg N / ha	0.19	27.11	24.64
S.Em±	0.004	0.66	0.38
CD @ 5 %	0.01	1.94	1.12
Interaction (S x N)			
S ₁ N ₁	0.17	28.36	20.43
S ₁ N ₂	0.19	27.91	20.08
S ₁ N ₃	0.18	28.08	20.72
S ₁ N ₄	0.20	30.68	24.72
S ₂ N ₁	0.19	27.13	22.03
S ₂ N ₂	0.14	21.69	21.11
S ₂ N ₃	0.22	29.54	23.33
S ₂ N ₄	0.18	24.59	24.53
S ₃ N ₁	0.19	25.26	22.18
S ₃ N ₂	0.18	24.73	24.52
S ₃ N ₃	0.22	25.38	24.02
S ₃ N ₄	0.19	26.07	24.68
S.Em±	0.008	1.14	0.66
CD at 5 %	0.02	3.36	1.94
CV (%)	7.48	7.45	5.04

* NS: Non significant

supplied with lower dose of nitrogen N₁ (60 kg / ha) recorded early flowering (114.22 days) followed by N₂ (123.44 days) and N₃ (124.11 days). Maximum days (130.33 days) for first flowering was noticed in higher nitrogen level 150 kg / ha (N₄). The interaction effect of spacing and nitrogen levels was found to be non-significant for days to first flowering. However, minimum days to first flowering (111.33 days) was observed in the treatment combination S₂N₁. Maximum days to first flowering (130.67 days) was recorded in S₂N₄ and S₃N₄ treatment combination (Table-1). This may be attributed to the competition among plants for nutrients, water and sunlight thus forcing the plants to turn to reproductive phase early as reported by Marutiprasad (2002) in davana. The data in Table 2 indicate that the spacing levels had non-significant effect on days to fifty per cent flowering. However, days to fifty per cent flowering ranged between 140.08 days to 143.58 days. Application of nitrogen had significant effect on days to fifty per cent flowering. Plants supplied with 60 kg N / ha (N₁) recorded minimum days to fifty per cent flowering (133.44 days) followed by N₂ (141.78 days) and N₃ (144 days). Maximum days to fifty per cent flowering (147.11 days) was noticed in N₄ (150 kg N / ha). Days to fifty per cent flowering did not differ significantly due to interaction of spacing and nitrogen levels. The results were in comparison with that of Yadav *et al.* (2000) in fennel.

Significant variation in number of flowers per plant (Table-2) was observed due to different spacing levels. Among spacing levels, plants spaced at 45 x 60 cm (S_3) resulted in higher number of flowers per plant (552.92) and the lowest (536.92) was noticed in S_1 (45 x 30 cm). Nitrogen levels had a significant effect on number of flowers per plant. Plants supplied with higher level of nitrogen N_4 (150 kg N / ha) produced more number of flowers per plant (572.22) followed by N_3 (546.56) and N_2 (541.78). Minimum number of flowers per plant (520.33) was observed in N_1 (60 kg N / ha). The interaction between spacing and nitrogen levels was found to be non-significant for number of flowers per plant. However, maximum number of flowers per plant (575.67) was noticed in the treatment combination S_3N_4 . While the minimum number of flowers per plant (511.67) was recorded in S_1N_1 treatment combination. This might be due to more number of branches, more plant spread which produced more flowering branches by the utilization of more space by the plants for production of flowers at this spacing as reported by Srekanth *et al.* (2007) and Kavita and Vadivel (2006). Wider spacing of 45 x 60 cm recorded significantly higher plant spread (N-S) of 45.76 cm and minimum (43.15 cm) was found in 45 x 30 cm (S_1). Among the nitrogen levels, 150 kg per hectare (N_4) recorded the maximum north-south plant spread (48.10 cm) and the least plant spread (N-S) of 41.94 cm was noticed with the application of 60 kg N / ha (N_1). Plant spread (E-W) differed significantly (Table 2) due to spacing. Among the spacing levels, spacing S_3 (45 x 60 cm) registered maximum plant spread (E-W) of 48.91 cm and least plant spread (E-W) of 46.09 cm was noticed in S_1 (45 x 30 cm). Influence of nitrogen levels on plant spread (E-W) was significant and the plant spread was registered maximum (53.11 cm) in higher nitrogen level of 150 kg N / ha (N_4) and minimum (43.02 cm) in N_1 (60 kg N / ha). The treatment combination S_3N_4 registered maximum plant spread (E-W) of 55.75 cm while the minimum plant spread (E-W) was registered in S_1N_1 (41.74 cm). The results obtained are in comparison with that of Lakshmpathai *et al.* (1998) and Singh (2000).

It is clear from the data that spacing had significant effect on fresh herbage yield per hectare. Among the different spacing levels, spacing of 45 x 30 cm (S_1) recorded significantly higher fresh herbage yield per hectare (16 t) and was followed by S_2 (14.06 t). The lowest fresh herbage yield per hectare (12.53 t) was noticed in S_3 . Application of nitrogen had significant effect on fresh herbage yield per hectare (Table-3). Among the different nitrogen levels, application of 150 kg N / ha (N_4) recorded the maximum fresh herbage yield per hectare (15.54 t) which was followed by N_3 (14.51 t) and N_2 (13.57 t). The minimum fresh herbage yield per hectare (13.16 t) was noticed in N_1 . Interaction of spacing and nitrogen also had significant effect on fresh herbage yield per hectare which ranged between 10.98 to 17.40 t. The S_1N_4 treatment combination recorded significantly higher fresh herbage yield per hectare (17.40 t) which was found to be on par with S_1N_3 (17.31 t) and S_3N_4 (16.59 t). The higher fresh herbage yield at wider spacing might be due to the fact that widely spaced plants put up better vegetative growth resulting in higher fresh herbage yield per plant. This might be due to the luxuriant growth of plants during vegetative phase and more number of plants per unit area due to closer spacing resulting in higher fresh

herbage yield. The results obtained are in conformity with Ramachandra *et al.* (2003) and Vijayaraghavan *et al.* (2005). It is evident from the data that spacing had significant impact on dry herbage yield per hectare. Among the spacing levels, plants spaced at 45 x 30 cm (S_1) produced significantly higher dry herbage yield per hectare (3.63 t) and was followed by S_2 (3.31 t). The least dry herbage yield per hectare (2.72 t) was observed in 45 x 60 cm (S_3). The data indicate the significant influence of nitrogen on dry herbage yield per hectare. Among nitrogen levels, application of higher dose of nitrogen 150 kg N / ha (N_4) produced maximum dry herbage yield per hectare (3.49 t) which was followed by 120 kg N / ha (3.22 t) and 90 kg N / ha (3.17 t). The minimum dry herbage yield per hectare (2.99 t) was noticed in 60 kg N / ha (N_1). Dry herbage yield per hectare varied significantly due to interaction of spacing and nitrogen levels (Table-3). Among the different treatment combinations, S_1N_4 combination recorded maximum dry herbage yield per hectare (4.16 t) and was found to be on par with S_3N_4 (3.77 t) and significantly superior over other treatment combination. The lowest dry herbage yield per hectare (2.12 t) was registered with S_3N_3 treatment combination. The results obtained are in conformity with Farooqi *et al.* (1990) and Randhawa *et al.* (1996).

It is clear from the results that spacing had significant effect on fresh root yield per hectare (Table 3). Among the spacing levels, spacing of 45 x 30 cm (S_1) recorded significantly higher fresh root yield per hectare (2.06 t) and was followed by S_2 (1.85 t). The lowest fresh root yield per hectare (1.76 t) was noticed in wider spacing 45 x 60 cm (S_3). Nitrogen significantly influenced the fresh root yield per hectare. Among nitrogen levels, application of 150 kg N / ha (N_4) produced the highest fresh root yield per hectare (2.09 t) which was followed by N_3 (1.88 t) and N_2 (1.83 t). The lowest fresh root yield per hectare (1.77 t) was observed in plants supplied with lowest level of nitrogen 60 kg N / ha (N_1). The data on interaction of spacing and nitrogen levels revealed significant effect on fresh root yield per hectare. The treatment combination S_1N_4 recorded maximum fresh root yield per hectare (2.34 t) which was found to be on par with S_1N_3 and S_3N_4 (2.13 t each) but significantly superior over other treatment combination. The minimum fresh root yield per hectare (1.53 t) was observed with S_3N_3 . This might be due to the higher growth of plants during vegetative phase and more number of plants per unit area at this spacing resulting in higher root yield per plot. The results obtained were in conformity with Harshavardhan *et al.* (2005), Subodhini *et al.* (2005) and Nandi and Chatterjee (1981).

Essential oil content in garden rue was found non-significant with respect to different spacing levels (Table-4). However, plants spaced at 45 x 30 cm (S_1) and 45 x 60 cm (S_3) recorded highest essential oil content (0.19%). The least essential oil content in herb (0.18%) was noticed in 45 x 45 cm spacing (S_2). The application of different levels of nitrogen had significant effect on essential oil content. Among different doses of nitrogen, application of 120 kg N / ha (N_3) registered the maximum essential oil content of 0.21 per cent which was followed by N_4 (0.19%) and N_1 (0.18%). The minimum essential oil content (0.17%) was observed in N_2 . The interaction of spacing and nitrogen levels was found significant with respect to essential oil content in herb. The treatment combination S_2N_3 and

S₃N₃ recorded highest essential oil content (0.22% each) and significantly superior over other treatment combination. The lowest essential oil content (0.14%) was noticed in S₂N₂. Essential oil yield per hectare was significantly influenced by different spacing levels (Table 4). The plants spaced at 45 x 30 cm (S₁) recorded significantly higher essential oil yield per hectare (28.76 kg) and was followed by 45 x 45 cm (25.74 kg). The lowest essential oil yield per hectare (25.36 kg) was noticed in 45 x 60 cm (S₃). The application of different levels of nitrogen also had significant influence on essential oil yield per hectare. Among different levels of nitrogen, application of 120 kg N / ha (N₃) recorded the maximum essential oil yield per hectare (27.67 kg) which was found to be statistically on par with N₄ (27.11 kg), and N₁ (26.92 kg). The minimum essential oil yield per hectare (24.77 kg) was observed in N₂. The interaction of spacing and nitrogen was found significant with respect to essential oil yield per hectare. Among different treatment combinations the highest essential oil yield per hectare (30.68 kg) was recorded in S₁N₄ which was found to be on par with S₂N₃ (29.54 kg), S₁N₁ (28.36 kg), S₁N₃ (28.08 kg) and S₁N₂ (27.91 kg) and significantly superior over other treatment combination. The least essential oil yield per hectare (21.69 kg) was noticed in S₂N₂ treatment combination. This increase in oil yield might be due to the accommodation of more number of plants per unit area and production of higher fresh herbage yields at this spacing level and this was in conformity with Ram *et al.* (1998) and Venkateshgowda (1989).

The effect of different spacing levels on the per cent dry matter was found significant (Table-4). The maximum per cent dry matter (23.85 %) was recorded in 45 x 60 cm (S₃) spacing which was followed by 45 x 45 cm (22.75 %). The minimum per cent dry matter (21.49 %) was noticed in 45 x 30 cm (S₁). Significant variation in per cent dry matter was exhibited by different nitrogen treatments. A linear increase in per cent dry matter was observed with increase in nitrogen level. Application of 150 kg N / ha (N₄) recorded the maximum per cent dry matter (24.64 %) and was superior over 120 kg N / ha (22.69 %) and 90 kg N / ha (21.91 %). The minimum per cent dry matter (21.55 %) was noticed in plants supplied with lowest dose of nitrogen 60 kg N / ha (N₁). Per cent dry matter also varied significantly due to the interaction of spacing and nitrogen. The highest per cent dry matter (24.72 %) was registered in S₁N₄ treatment combination and was statistically on par with S₃N₄ (24.68 %), S₂N₄ (24.53 %), S₃N₂ (24.52 %), S₃N₃ (24.02 %) and S₂N₃ (23.33 %) and significantly superior over other treatment combination. The lowest per cent dry matter (20.08 %) was recorded in S₁N₂. The results obtained were in conformity with Umesha *et al.* (1990).

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