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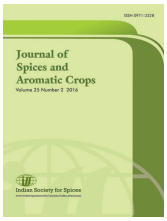

Effect of varying levels of nitrogen on growth, yield, quality and profitability of transplanted fennel (*Foeniculum vulgare* Mill.)

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Abstract

Field experiments were conducted at two adjoining farmer's field in tribal area of district Sirohi (Rajasthan) during two successive seasons from July 2012 to March 2013 and July 2013 to March 2014 to study the impact of varied levels of nitrogen (60, 90, 120 & 150 kg N ha^{-1}) on production, quality and profitability of transplanted fennel (*Foeniculum vulgare*). Application of nitrogen @120 kg ha^{-1} recorded the highest stem girth, number of roots $plant^{-1}$, root length, fresh weight of root and root: shoot ratio. The maximum value of number of umbels $plant^{-1}$, umbellate $umbel^{-1}$, number of seeds $umbel^{-1}$, test weight, seed yield, straw yield, harvesting index was also reported in same treatment. Similarly, volatile and total oil content, soluble sugar, total carbohydrate and overall quality of seeds were also higher with application of 120 kg N ha^{-1}, whereas, disease incidence significantly increased with application of higher dose of nitrogen (150 kg N ha^{-1}). The maximum net return and highest benefit: cost ratio was also recorded with application of 120 kg N ha^{-1}. However, some of the growth parameters (plant height, number of primary and secondary branches $plant^{-1}$, number of leaves, fresh weight of shoot and duration of flowering, protein and nitrogen content in seed were more with 150 kg N ha^{-1}.

Keywords: bio-chemical, days after transplanting (DAT), nitrogen, transplanted fennel, umbels

Introduction

Fennel (*Foeniculum vulgare* Mill.) is an herbaceous plant belonging to the family of *Apiaceae* and is a widely cultivated seed spice throughout the temperate and sub tropical regions of the world. Major production centers of fennel in India are Rajasthan, Gujarat, Andhra Pradesh, Punjab, Madhya Pradesh, Uttar Pradesh, Karnataka and Haryana. It is mainly grown in the *Rabi* season but in some parts of Southwest Rajasthan like Sirohi, Jalore, Jodhpur and Pali is grown in *Kharif-Rabi* season also by seedling transplanting method from month of July to March. The total area under fennel cultivation in Rajasthan is 58474 ha with a production 85189 t of having 14.5 qt ha^{-1} productivity, out of which maximum area of transplanted fennel is in district Sirohi *i.e.* 4091 hectare and 4236 t production with 10.35 q ha^{-1} productivity (Anonymous 2012). Because the fennel growers go behind the package of practices of *Rabi* season (Direct seed sowing)

crop which is short duration (4-5 months) with low yield whereas, the transplanted fennel is long duration (7-8 months), high yielding crop (maximum potential around 20-28 q ha^{-1}). The transplanted fennel production potential is 2 to 3 times more than direct seed sowing fennel (Bhardwaj 2014) and the production technology and management practices are different for transplanted fennel.

Among the various factors which can increase yield, the application of N fertilizer is considered to be the most important one (Chatzopoulou *et al*. 2006). Nitrogen is one of the major elements for growth and development of plant and judicious application of N fertilized help in quantum and quality production of crops.

Application of N at a rate of 200 kg ha^{-1} resulted maximum improvement in growth, yields and quality parameters like protein, carbohydrate, soluble sugar, volatile oil and total oil content (Khalid 2012). Hansraj & Thakral (2008) observed the highest growth and yield parameters at 100 kg N ha^{-1}. Whereas, Damato *et al.* (1994) reported that N applied at the rate of 300 kg ha^{-1} increased test weight and seed yield of fennel. As soils of Rajasthan are deficient in N, application of adequate amount of N is considered to be most important (Bhardwaj *et al*. 2013). So, there has been a great variation in the use of N for obtaining higher seed yield and the information in Rajasthan about the use of N for transplanted fennel is almost lacking. The present study was therefore planned to evaluate the effect of N on growth, yield, quality and profitability of transplanted fennel, in Southwest Rajasthan.

Materials and methods

The field experiment was conducted on two adjoining sites at Kacholi village in district Sirohi (Rajasthan) during two consecutive seasons (*Kharif-Rabi*) from July 2012 to March 2013 and July 2013 to March 2014. The soil of experimental field was uniform in fertility, sandy loam in texture, low in organic carbon (0.58% and 0.62%), medium in available P (25.5 kg and 21.5 kg ha^{-1}) and high in K (280.0 kg and 285.0 kg ha^{-1}) with saturated extraction electrical conductance of 2.0 $ds.m^{-1}$ and slightly alkaline reaction (pH 8.2) during both the years of experimentation, respectively. The abiotic factors *viz*., average minimum and maximum temperatures were 28.0° + 5.0°C and 38.0° + 5.0°C, average relative humidity of 58.0 + 10.0% and 585.0 mm rainfall per annum were recorded during the experimentation.

The investigation comprised of four treatments *i.e.* N_1 (60 kg N ha^{-1}), N_2 (90 kg N ha^{-1}), N_3 (120 kg N ha^{-1}), N_4 (150 kg N ha^{-1}) and it was laid out in completely randomized design with five replications. The net plot size was 2.5 m × 3.3 m. Full dose of organic matter (200 q ha^{-1}) was applied at the time field preparation and half dose of phosphorus (30 kg ha^{-1}) and potash (20 kg ha^{-1}) with one fourth dose of nitrogen *i.e.* N_1 (15.0 kg ha^{-1}), N_2 (22.5 kg ha^{-1}), N_3 (30.0 kg ha^{-1}), N_4 (37.5 kg ha^{-1}) was applied at the time of seedling transplanting as basal dose. Second half dose of phosphorus (30 kg ha^{-1}) and potash (20 kg ha^{-1}) with one fourth dose of N was applied at 30 days after transplanting by side dressing method and pursues a light irrigation. Remaining dose of N was applied at 45 and 60 days after transplanting by top dressing method after light irrigation. The intercultural operations (weeding, irrigation, mulching, etc.) and plant protection measures were followed uniformly for the all plots during the entire period of experimentation of both years. In a well prepared field, 45 days old seedlings of fennel local cultivar '*Abu saunf*' were transplanted by paired row planting at 210 cm/ 120 cm × 25 cm (24271 plants ha^{-1}) during first week of August. Light irrigation was applied immediately after transplanting.

Five randomly selected plants were used for observations on plant growth, yield attributes and yield from each plot. Plant height (at 90 DAT and at harvesting) was measured from soil surface to the highest shoot tip by straightening all branches. Stem girth was measured from one cm above the base of the stem using vernier calliper. Observations on number of branches, number of nodes on main shoots at harvest, number of leaves, first flower initiation, last flower initiation, duration of flowering (days), number of umbel $plant^{-1}$, number of umbellate

umbel^{-1}, number of seeds umbel^{-1} were recorded by standard counting method. Number of roots and root length was measured by destructive sampling. Stem and root were weighed to record the fresh weight. Length and width of seed was calculated by using vernier caliper and expressed in millimeter. Test weight was measured by weighing 1000 seeds and expressed in gram. The total seed yield, straw yield and biological yield was calculated by weighing total seed, straw produced and is presented on hectare basis. The Harvest Index was calculated using the following formula:

Harvest Index (%) = Economic yield / Biological yield × 100

In order to determine the of volatile oil per cent and total oil content (%), a sample of 100 g of fennel seeds from the each plot were crushed in electric grinder and were mixed with 500 ml distilled water and then were subjected to hydro-distillation for 3 hours using a Clevenger-type apparatus (Kapoor *et al*. 2004; Darzi *et al*. 2012). For fixed oil extraction from fennel seeds the 50 g of seed were crushed to coarse powered and extracted with petroleum ether (40-60^{o}C) in a Soxhlet extraction method (AOAC 1970). Soluble sugars concentrations in seeds (collected at the end of the first and second years of each treatment) were determined according to Ciha & Brun (1978) with some modifications. For measurement of total carbohydrates a phenol-sulfuric acid assay was used (Dubois *et al.* 1956). A volume of 0.5 mL of 5% (v/v) phenol solution and 2.5 mL of concentrated sulfuric acid were added to 0.5 mL aliquots. The mixture was shaken, heated in a boiling water-bath for 20 min and cooled to room temperature. The absorption was then determined by spectrophotometry at 490 nm. N and protein content in seed and N content in soil of both years of each treatment were determined by using the micro kjeldhal methods described by Black (1965). Furthermore, the net return was calculated by subtracting cost of each treatment from gross return. The gross return was calculated from yield multiplied by average market rate during the period of investigation. The benefit cost ratio was calculated by dividing net return to total cost. Disease incidences in plants were recorded after appearance of disease symptoms, which were counted at 150 DAT and data presented in per cent basis. The overall quality (taste, brightness, seed colour, size and shape) and consumer preference of seed was done by a panel of five semi-trained judges by scoring based visual inspection (Bhardwaj *et al*. 2013). The significance of variance in the pooled data of two years was done by the standard procedure described by (Steel *et al*. 1997). Significance of difference among the treatments effect was analyzed statistically using Fishers analysis of variance technique and least significant difference (LSD), at 5% probability level to compare the difference among treatment means.

Results and discussion

Vegetative growth parameters

The results of the analysis variance showed that the vegetative parameters were significantly affected by all treatments (Pd"0.05) in this experiment (Table 1 & Fig. 1). Mean comparison table showed that the application of highest level of N (150 kg N ha^{-1}) resulted in higher plant height of 77.26 cm (90 DAT), 183.45 cm (at harvesting), maximum number of primary branches plant^{-1}, secondary branches plant^{-1}, number of nodes on main shoot, number of leaves plant^{-1} and highest fresh weight of shoot. The crop was fertilized with 120 kg N ha^{-1}, recorded highest stem girth, maximum number of roots plant^{-1}, highest root length, fresh weight of root and root/shoot ratio. The lowest value of all vegetative parameters was obtained with 60 kg N ha^{-1}. The enhancement in vegetative parameters as a result of application of N might be due to fact that N favours better growth and development of plants. But excess amount of N significantly reduces number of roots plant^{-1}, root length and fresh weight of root. Similarly, Salarazai *et al*. (2005) observed that there was gradual improvement in growth and yield characters of fennel with each increased level of N up to 80 kg ha^{-1} and highest level (120 kg N ha^{-1}) produced significantly low values for all the growth and yield components. These results are in close agreement with the observations of Hansraj & Thakral (2008) in fennel and Patel *et*

Table 1. Effect of varying levels of N on the vegetative growth of fennel

Treatments	Plant height at 90 DAT (cm)	Plant height at harvest(cm)	Number of primary branches plant^{-1}	Number of secondary branches plant^{-1}	Number of nodes on main shoot at harvest
N_1(60 kg N ha^{-1})	59.19	120.65	7.38	15.89	8.62
N_2 (90 kg N ha^{-1})	67.66	138.90	10.33	20.97	11.33
N_3 (120 kg N ha^{-1})	72.88	162.60	12.91	25.26	13.53
N_4 (150 kg N ha^{-1})	77.26	183.45	14.51	28.93	15.35
S Em. ±	0.907	2.389	0.134	0.590	0.271
P<0.05	3.561	9.381	0.528	2.317	1.067
Treatments	Number of leaves plant^{-1}	Stem girth (cm)	Number of roots plant^{-1}	Root length (cm)	Fresh weight of shoot (g)
N_1(60 kg N ha^{-1})	16.52	9.06	16.50	19.13	626.47
N_2 (90 kg N ha^{-1})	22.71	9.79	20.19	23.47	690.17
N_3 (120 kg N ha^{-1})	28.25	12.50	27.01	27.79	760.24
N_4 (150 kg N ha^{-1})	32.45	10.81	23.79	26.11	809.72
S Em. ±	0.769	0.193	0.272	0.530	7.361
P<0.05	3.020	0.760	1.068	2.082	28.895
Treatments	Fresh weight of root(g)	Root/shoot ratio	Flower initiation (DAT)	Flower continued (DAT)	Duration of flowering (days)
N_1 (60 kg N ha^{-1})	123.49	0.197	80.04	179.85	99.81
N_2 (90 kg N ha^{-1})	139.12	0.202	85.40	193.72	108.32
N_3 (120 kg N ha^{-1})	153.28	0.202	88.49	205.83	117.34
N_4 (150 kg N ha^{-1})	148.03	0.183	91.43	216.95	125.52
S Em. ±	1.559	0.002	1.368	2.011	1.694
P<0.05	6.120	0.011	5.370	7.897	6.651

al. (2013) in coriander. Days taken to bloom are decided by C: N ratio. The plants tend to bloom earlier with higher C: N ratio. The data in Table 1 indicated that each N increment from 60 to 150 kg N ha^{-1} significantly delayed flowering in fennel. Maximum days required for first flower initiation, last flower initiation and maximum extended flowering duration was also reported in higher dose of N (150 kg N ha^{-1}). Deferred flower initiation and increase duration of flowering as a result of application of N might be due to fact that the higher availability of N significantly increases duration of the vegetative phase of plants and delayed initiation of reproductive phase. Similar results were reported by Bhardwaj (2011) & Bhardwaj *et al*. (2013) in fennel.

Yield and yield attributes

Yield attributing characters *viz*., number of umbels plant^{-1}, number of umbellates umbel^{-1}, number of seeds umbellate^{-1} as well as test weight of seed recorded higher with higher levels of N application (90, 120 and 150 kg ha^{-1}) over their preceding levels, except in case of test weight of seed where 90 kg N ha^{-1} with 120 kg N ha^{-1} and 120 kg N ha^{-1} with 150 kg N ha^{-1} were not differ remarkably. Maximum number of umbels plant^{-1}, number of umbellates umbel^{-1}, maximum number of seeds umbel^{-1}, highest length and width of seed, maximum test weight were produced with 120 kg N ha^{-1} (Table 2). An adequate supply of N is associated with high photosynthetic activity leading to reproductive

Table 2. Effect of varying levels of N on the yield and yield attributes of fennel

Treatments	Number of umbels plant^{-1}	Number of umbellate umbel^{-1}	Number of seeds umbel^{-1}	Length of seed(mm)	Width of seed(mm)
N_1 (60 kg N ha^{-1})	14.84	14.29	375.48	5.06	1.29
N_2 (90 kg N ha^{-1})	17.94	18.14	408.21	6.46	1.89
N_3 (120 kg N ha^{-1})	20.02	22.53	427.91	7.11	2.35
N_4 (150 kg N ha^{-1})	18.11	21.16	422.06	6.61	2.21
S Em. ±	0.343	0.343	4.214	0.088	0.028
P<0.05	1.348	1.348	16.544	0.349	0.112
Treatments	Test weight (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield(q ha^{-1})	Harvesting Index (%)
N_1 (60 kg N ha^{-1})	10.91	14.75	70.81	85.56	13.99
N_2 (90 kg N ha^{-1})	11.94	21.22	76.49	97.71	18.05
N_3 (120 kg N ha^{-1})	12.29	25.55	82.04	107.59	22.99
N_4 (150 kg N ha^{-1})	12.04	22.33	81.36	103.60	22.64
S Em. ±	0.071	0.459	0.898	1.422	0.543
P<0.05	0.279	1.804	3.526	5.583	2.132

growth (yield attributes) associated with keeping the balance between plant source and sink which can produce more dry matter (fully filled seeds) and physiologically more stout and healthy plants with deep root system, where as the excess dose of N leading to vigorous vegetative growth with sallow root system and physiologically weak, as a result reduce growth and development. The increase in test weight with the increase in N fertilization level up to 120 kg N ha^{-1} can be caused by the increase in plant photosynthesis potential and synthesis of carbohydrates and their accumulation in seeds. Rassam *et al*. (2007) found that the increase in N level up to 120 kg ha^{-1} increased umbel number per plant which is in agreement with the result of the current study. Nakhaei *et al*. (2012) also reported that higher N increased the yield attributing characters like umbels plant^{-1}, umbellets umbel^{-1}, seeds umbellet^{-1}, seeds umbel^{-1} and finally seed yield of fennel. The present finding further confirmed the earlier reports of Hansraj & Thakral (2008), Ayub *et al*. (2011), Bhardwaj (2011) in fennel, Patel *et al.* (2013) in coriander.

There were significant (P<0.05) differences between the seed yield, straw yield, biological yield and harvesting index values of fennel in the both experimental years (Table 2) due to increasing the level of N. The highest value of seed yield, straw yield, biological yield and harvesting index was reported in 120 kg N ha^{-1} which was significantly superior to all other level of N but *at par* with 150 kg N ha^{-1} except in case of seed yield and remarkably higher than 60 kg N ha^{-1}. The respective percentage increase in seed yield, straw yield, biological yield and harvesting index under application of N @120 kg ha^{-1} was 73.22%, 15.85%, 25.74% and 64.33% over that of with 60 kg N ha^{-1}, respectively. Relative consistency in seed yield, straw yield, biological yield and harvesting index with increase in N dose from 60 to 150 kg N ha^{-1} indicated that the application of N greater than 120 kg ha^{-1} may not be beneficial for harvesting economical yield of fennel. Ayub *et al*. (2011) and Bhardwaj *et al*. (2013) strongly supported the finding that fresh biomass and yield of fennel was increased when crop was supplied balance dose of N which may be due to better development of the crop but excess dose of N reduced economic yield. Similar findings are also reported by Rampratap *et al.* (2003) in fennel, Rana *et al*. (2012) in black cumin, Patel *et al*. (2013) in coriander, Bhardwaj (2014) in fennel.

Table 3. Effect of varying levels of N on the bio-chemical traits of fennel seed (pooled)

Treatments	Soluble sugars (%)	Total carbo-hydrate (%)	Crude protein content (%)	Nitrogen content (%)	Volatile oil content (%)	Total oil content (%)
N_1 (60 kg N ha^{-1})	2.99	9.68	11.56	1.97	0.561	3.98
N_2 (90 kg N ha^{-1})	3.65	11.89	16.06	2.70	0.623	5.19
N_3 (120 kg N ha^{-1})	4.05	13.58	18.56	3.10	0.671	5.89
N_4 (150 kg N ha^{-1})	3.99	13.25	19.69	3.28	0.660	5.73
S Em. ±	0.116	0.223	0.565	0.116	0.005	0.230
P<0.05	0.459	0.877	2.220	0.459	0.020	0.903

Bio-chemical parameters

Total carbohydrate and soluble sugar content: Table 3 shows that total contents of carbohydrates and soluble sugars in fennel seeds increased significantly with increasing N rates. The highest contents of total carbohydrates and soluble sugars were recorded when plants were treated with 120 kg N ha^{-1} which was significantly superior to all other level of N but *at par* with 150 kg N ha^{-1}. Total carbohydrates were 28.71% and soluble sugars were 26.17% higher than the application of 60 kg N ha^{-1} in fennel. N fertilization increased essential oil, fixed oil, total carbohydrates, soluble sugars and NPK content of anise, coriander and fennel plants (Khalid 2012). Similar response to N in fennel crop was also reported by Bhardwaj *et al*. (2013) & Khalid (2013).

Volatile oil and total oil content in seed: Generally, all levels of N progressively increased the volatile oil and total oil content of fennel seed (Table 3). The application 120 kg N ha^{-1} seemed to be optimal for obtaining a higher concentration of volatile oil (0.671%) and total oil content (5.89%) which was significantly superior to other lower doses of N, but *at par* with higher dose of nitrogen. The effect of different N treatments on volatile oil and total oil content may be due to its effect on enzyme activity and metabolism of oil production in fennel. These results were in accordance with those obtained by Khalid (2012 & 2013) and Bhardwaj *et al*. 2013 in fennel. Ashraf *et al*. (2006) on cumin; Akbarinia *et al*. (2007) on coriander; Hellal *et al*. (2011) on *dill* (*Anethum graveolens* L.), who reported that N has a positive effect on the quantity of essential oil extracted from *Apiaceae* plants. The application of nitrogen not only increased seed yield but also improved oil contents in fennel (Ayub *et al*. 2011).

Total nitrogen and protein content: Application of 150 kg N ha^{-1} resulted in the highest N and protein content in fennel seeds, which was significantly superior to the other lower levels of N but *at par* with 120 kg N ha^{-1} (Table 3). These results may be due to the influence of N on the ribosome structure and the biosynthesis of some hormones (gibberellines, auxins, cytokinins) involved in protein synthesis (El-Wahab & Mohamed 2007). Increase in protein content can be ascribed to increase in N uptake at higher levels and also as N is a part of amino acid, which constitutes building blocks of protein and that might have resulted in higher protein content. Similar increasing trend in protein content with N application was also reported by Khalid (2013) in some apiaceae crops, Patel *et al*. (2013) in coriander and Bhardwaj (2014) in fennel.

Economics and quality parameters

Economics: Varied level of n was also significantly influenced the gross return, net return and benefit cost ratio in fennel (Table 4). Application of 120 kg N ha^{-1} proved profitable and showed maximum gross return, net return and highest benefit cost ratio due to high yield with good quality seed obtain. This treatment was significantly superior to rest of the N levels. The minimum gross return, net return and lowest benefit cost ratio was recorded from those plots where 60 kg N ha^{-1} was applied. Ayub *et al*. (2011) reported that the net income

Table 4. Effect of varying levels of N on the economics, disease incidence, quality seed and N content in soil

Treatments	Gross return (Rs)	Net return (Rs)	B: C ratio	Disease incidence (%)	Quality score of seed*	Nitrogen content in soil (kg ha^{-1})
N_1 (60 kg N ha^{-1})	135339.20	95995.25	2.44	5.81	3.39	123.17
N_2 (90 kg N ha^{-1})	207308.40	167544.40	4.21	6.24	3.61	128.96
N_3 (120 kg N ha^{-1})	271741.80	231557.80	5.76	7.74	3.93	135.82
N_4 (150 kg N ha^{-1})	230875.10	190271.10	4.69	9.97	3.82	146.35
S Em. ±	1073.46	1072.00	0.027	0.191	0.051	1.533
P<0.05	4213.64	4207.91	0.106	0.750	0.203	6.019

*Marking on the basis of quality of seed (1=very poor quality; 2=poor quality; 3=average quality; 4=good quality; 5=excellent quality)

and B:C ratio increased up to Rs. 28100.0 and 2.19, respectively with increased N level up to 90 kg ha^{-1} and then it started to decrease. Similar results were reported by Bhardwaj (2011) and Bhardwaj *et al*. (2013) in fennel.

Disease incidence in crop: The increase in N levels caused a significant increase in disease incidence (gamosis or *sugari* disease) at the time of flowering. Maximum disease incidence of plants was reported by applying 150 kg N ha^{-1} while the minimum was observed in case of 60 kg N ha^{-1}. The increase in disease incidence with increasing dose of N may be due to increase tenderness in plants and reduce disease resistance. In case of higher dose of N the crop logging was augment at the time flowering and this condition favour disease incidence in fennel crop. Higher dose of N added moisture at the time of flowering significantly increase crop logging, succulence and sugari disease incidence in fennel (Bhardwaj 2014). These results are inconsonance with those reported by Bhardwaj *et al*. (2013) and Bhardwaj & Agrawal (2014) in fennel.

Overall quality of seed: The overall quality of seed increased with increased level N up to 120 kg ha^{-1} and then it started to decrease, but decrease could not reach a significant level (Table 4). The maximum quality score (3.93) was also observed due to application of N at 120 kg ha^{-1}. N application has influenced the physiological processes such as photosynthesis, which ultimately resulted in fully filled quality seed of fennel (Ayub *et al*. 2011). These findings were well supported by Khalid (2013) in some apiaceae crops, Patel *et al*. (2013) in coriander and Bhardwaj (2014) in fennel. It may be concluded that transplanted fennel should be fertilized with 120 kg N ha^{-1} for significant increase in economically acceptable yield, quality and profitability.

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