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Growth kinetics of fennel with nitrogen application in Typic Haplustepts

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ABSTRACT

To assess the growth kinetics and yield performance of fennel (Foeniculum vulgare), field experiments were carried out with various nitrogen levels i.e., 40, 60, 80, 100 and 120 kg ha^{-1}. Results revealed that all the growth parameters were higher with increased doses of nitrogen. However, plants height and number of branches were only higher with alternate higher level of nitrogen. Moreover tremendous increments were observed in number of umbel and umbellates plant^{-1}resultant yield was also higher for about 1.5 times with 120 kg N as that of absolute control. Seed yield, number of umbel and number of umbellates were highly correlated with N levels and their corresponding r^2 values were 0.92, 0.95 and 0.98, respectively. Likewise, seed yield of fennel was directly correlated with number of umbel and number of umbellate plant^{-1} bears r^2 value 1.0 and 0.97, respectively. The relative growth rate of root was higher exponentially with time which indicates that fennel root remains in active phase even at maturity of crop. However, relative shoot growth was very slow up to 90 days there after it increased linearly up to the age of 180 days or maturity. Relative growth rate of root and shoot with nitrogen levels slacked at early growth stage, while its response to higher level of nitrogen was distinctively higher and hence at the age of 90 to 180 days was nearer to linearity. Relative growth rate of root was much slower than the relative shoot growth particularly at later stages. Shoot-root ratio was highest at 120 days followed by 60 days resulted linear shoot growth at 120 days with N levels. Based on the growth kinetics/phenological parameters, fennel is an 'Herbaceous perennial bushy' plant rather mentioned in the literature as 'perennial plant grown as an annual crop'. Due to slower growth up to 90 days, it can be taken successfully in relay cropping which can increase crop intensity in per unit time and area.

Key words: F*ennel, Foeniculumvulgare, nitrogen, growth kinetics, yield.*

INTRODUCTION

Study of growth kinetics of crop plants is very important to assess the crop response to nutrients along with other variables like climatic and edaphic for a location specific, which determines the probable yield and behaviour of plant. For crop production point of view, study of growth kinetics are very important for inter cropping, weed management, nutrient requirement and their uptake kinetics. Relative growth rate (RGR) is a prominent indicator of plant strategy with respect to productivity as related to environmental stress and disturbance regimes particularly nutrient input. RGR is the (exponential) increase in size relative to the size of the plant present at the start of a given time interval, expressed in this way. Growth rates can be compared among species and individuals that differ widely in size. By separate measurement of leaf, stem and root mass as well as leaf area (LA), good insight into the components underlying growth variation can be obtained in a relatively simple way. These underlying parameters are related to allocation (leaf-mass fraction, the fraction of plant biomass allocated to leaf), leaf morphology and physiology (unit leaf rate, the rate of increase in plant biomass per unit LA, a variable closely related to the daily rate of photosynthesis per unit LA; also known as net assimilation rate) (Pérez-Harguindeguy *et al.*, 2013).The potential RGR of plants (the rate of increase in biomass per unit biomass) and its relationship with different plant traits has been studied extensively by various workers (Lambers & Poorter, 1992;Poorter& Van der Werf, 1998).Partitioning of dry matter between the root and shoot tissues of a plant is regulated precisely at a constant value for a given genotype under specified environmental conditions, carbon fixation and partitioning. But individuals of different species or of the same species under different environmental conditions show characteristic variation in the root-shoot ratio (Gadgil and Gadgil, 1979).

Relationship between N supply and biomass accumulation in crops, relies on the inter regulation of multiple crop physiological processes. Among these processes, N uptake, crop C assimilation and thus growth rate, and C and N allocation between organs and between plants, play a particular role. Under suboptimal N supply, N uptake of the crop depends on soil mineral N availability and distribution, and on root distribution. Under ample N supply, N uptake largely depends on growth rate via internal plant regulation. Carbon assimilation of the crop is related to crop N through the distribution of N between mature leaves with consequences for leaf and canopy photosynthesis (Gastal and Lemaire 2002). When sub optimal source of external N were available, RGR was maintained at a rate which was dependent on the rate of nitrate uptake by the lettuce (*Lactucasativa*) root (Walker *et al*, 2001).There are few studies carried out on fennel for growth response to N supply, however these are limited up to growth parameters only. Yield parameters viz. plant height, number of branches plant^{-1}, stem diameter, number of leaves plant^{-1}, length of internodes, number of tillers plant^{-1} and plant spread, also increased with increasing dose of nitrogen (0, 30, 60 and 90 kg N ha^{-1}) and phosphorus (0, 25 and 50 kg P ha^{-1}), and maximum was found in the 90 kg N and 50 kg P ha^{-1} (Rai *et al.* 2002). Basal application of 90 kg N + 40 kg P + 50 kg K ha^{-1} proved best for most of the parameters studied. Among the spray treatments, 20 kg N and 2 kg P ha^{-1}, was best for essential oil content and fruit yield (Saadul, 2000).Seed yield was higher under the 80 kg N ha^{-1} over the rest of the treatments i.e. 80, 100 and 120 kg N ha^{-1}(Tank *et al,* 2006).Uptake pattern of nutrients in fennel was worked by Aishwath (2017) and growth kinetics in coriander with lime (Aishwath *et al.*, 2015). Based on the above information, none of the work available on growth kinetics. Therefore, present investigation was carried out to assess the growth response of fennel to nitrogen input and growth kinetics with or without N input for behaviour of crop under such stresses.

MATERIAL AND METHODS

Location and climate

Field experiments were carried out during *Rabi* season of 2015-2016 and 2016-2017 at ICAR-National Research Centre on Seed Spices, Tabiji, Ajmer, Rajasthan, India. This was laid between 74° 35’39” to 74° 36’ 01”E longitude and 26° 22’12” to 26° 22’ 31” N latitude. Climate of the Ajmer area characterized as semi-arid. The average annual rainfall of the area is 536 mm and most of it (85-90%) receives from June to September. July and August are most rainy months contributing 60.0% of the average rainfall. Soil moisture control section remains dry for more than 90 cumulative days and hence moisture regime classified as Ustic. Mean annual temperature is 24.5 to 25.0°C. January is the coolest month of the season and temperature remains around 7.0°C. Sometimes, frost is also occurring in this month

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Treatments and cultural practices

The field experiments were carried out consecutively two years during 2015-16 and 2016-17 in sandy loam soil of Ajmer, Rajasthan. There were five levels of N i.e., 40, 60, 80, 100 and 120 kg ha^{-1} and these were compared with control (without nitrogen with basal doses of other nutrients) and absolute control (without any nutrients/input).The treatments were arranged in a Randomized Block Design (RBD) with three replications. Seeds of the crop (Ajmer Fennel-1)were sown in the 50 cm line to line apart and distance from plant to plant was maintained at 15 cm. Cultural practices were uniformly followed during the growing seasons in both the years. The crop was harvested when seeds matured. After harvest, seeds were separated from the straw by beating of bundles thereafter winnowing.

Growth kinetics/analysis

Relative growth rate (RGR) is a prominent indicator of plant strategy with respect to productivity as related to environmental stress and disturbance regimes. RGR increases in size relative to the size of the plant present at the start of a given time interval. Hence plant samples were collected at various growth stages i.e. 60, 90, 120 and 180 days. Root and shoot parts were washed with tap water and then 0.1M HCl followed by deionized water. After air dry, plant samples were dried in oven at 70^{o}C till the constant weight obtained. Root and shoot weight measured separately and relative growth rate (RGR) was calculated by the following method –

Growth rate plant^{-1} day^{-1} (mg) = (W/D)*1000

W = Dry weight of shoot or root (gm.)

D = No. of days

However, root-shoot ratio was calculated by the following way-

Shoot-root ratio = W_1/W_2

W_1 = Shoot dry weight plant^{-1}

W_2 = Root dry weight plant^{-1}

Soil Analysis

Soil samples were collected from the surface (0-15 cm depth) before sowing of seeds and various crop growth stages including at maturity during both the years. Samples were air dried and powdered with wooden mortar and pestle and passed through a 2 mm stainless steel sieve. Experimental soil was analyzed for texture (International Pipette Method), EC and pH (Richards, 1954), organic carbon content by rapid chromic titration (Walkley and Black, 1934), available N by alkaline permanganate (Subbiah and Asija, 1956), available P by 0.5 M $NaHCO_3$ extractable P (Olsen, *et al.*, 1954), available K by 1N NH_4OAc extracts method (Jackson, 1973), available micro-nutrients by DTPA (Lindsay, and Norvell, 1978).

Texture of experimental soil was sandy loam. Soil EC, pH and organic carbon were 0.29dSm^{-1}, 7.9 and 0.27%, respectively. However, soil available N, P and K were 115.2, 9.6 and 239.3 kg ha^{-1}, respectively. Micronutrient status like iron, zinc, manganese and copper of the soil was 10.3, 1.75, 21.35, 2.09 kg ha^{-1}, respectively.

Statistical Analysis

The data during both the years were pooled and analyzed by ANOVA and treatment differences were expressed for Least Significant Differences (LSD) at 5% probability to determine the significance among the treatment means (Cochran and Cox, 1987).

RESULTS AND DISCUSSION

Growth, yield and their parameters

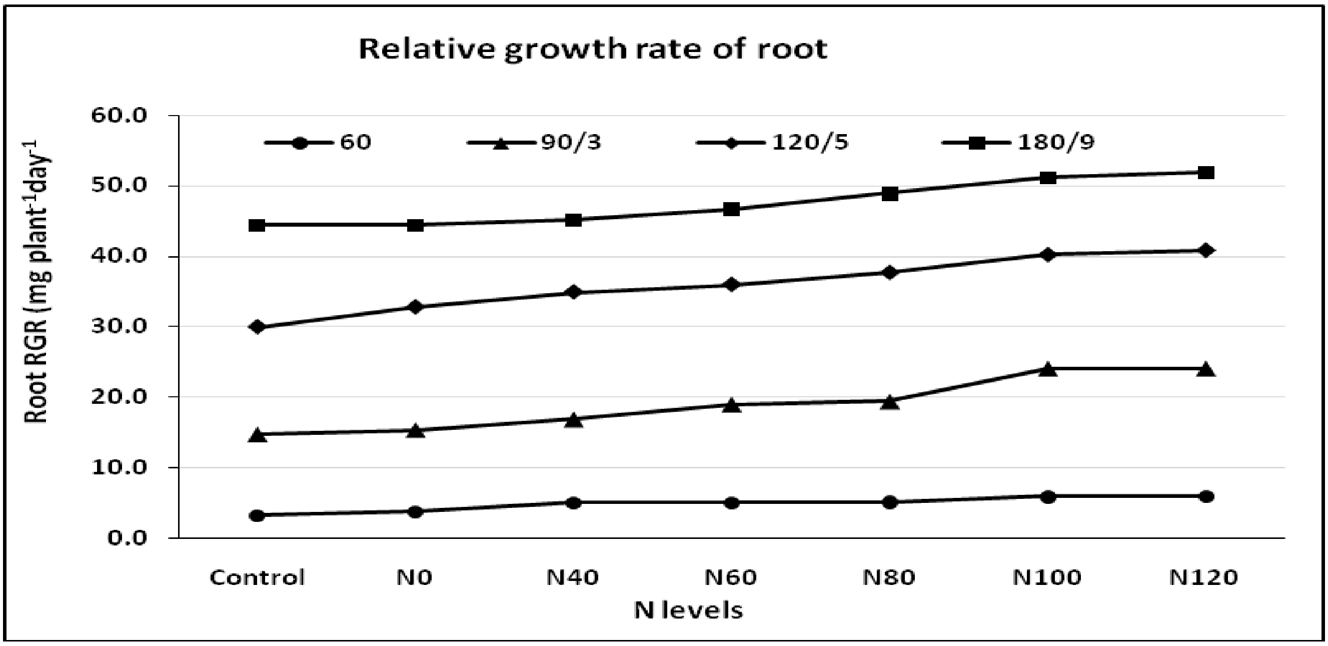
Plants were the tallest with 120 kg N ha^{-1}(Table 1). No significant effect was observed with each successive levels of N. however plant height was more with all N levels as compared to control. Number of primary branches were found to be maximum at 120 kg N ha^{-1}. Number of primary branches plant^{-1} increased with almost all levels of N. Number of secondary branches were higher with higher levels of N over their lower level, however these were higher with lower levels of N in comparison to control. This is because of higher input of N enhanced higher carbon assimilation; N being an integral part of chlorophyll. Saadul (2000) and Rai*et al* (2002) also reported higher growth parameters of fennel with nitrogen doses. Number of umbels plant^{-1} increased with each alternative levels of N. however, the difference was more distinctive at higher levels of N. Moreover, number of umbellates plant^{-1} was more over the control, whereas no statistical difference was obtained within the N levels.

Table 1: Growth parameters of fennel with applied graded levels of N

Treatment	Plant height (cm)	No. of Primary branches	No. of Secondary branches	No. of umbel plant^{-1}	No. of Umbellate umbel^{-1}	Seed (q/ha)	Stover (q/ha)
Control	182.93	10.33	20.22	22.11	25.78	17.2	79.1
N_0	190.93	10.67	20.89	27.89	28.56	19.4	80.6
N_{40}	195.77	10.89	22.00	27.89	29.00	22.0	81.7
N_{60}	200.69	11.33	22.33	28.89	30.33	22.6	101.5
N_{80}	202.33	11.89	22.44	29.44	30.89	23.9	105.8
N_{100}	205.22	12.11	23.22	30.56	31.56	24.1	107.4
N_{120}	208.73	12.56	23.56	31.67	36.56	24.3	109.1
Mean	198.09	11.40	22.09	28.35	30.38	21.93	95.0
CD at 5 %	5.95	0.41	0.98	0.82	2.32	1.3	14.7

Most of the growth and yield parameter were at par with control and absolute control, while tremendous increments were observed in number of umbel and umbellatesplant^{-1}, which was around 1.5 times higher with 120 kg of N as compare to absolute control. Resultant seed yield was also higher for about 1.5 times with 120 kg N as that of absolute control, besides that seed yield increased with each successive levels of N. Likewise strover yield was also followed similar trend to seed yield, however it was at par with almost all higher levels of N. Seed yield, number of umbel and number of umbellates were highly correlated with increased N levels (0-120 kg ha^{-1}) and their corresponding r^2 values were 0.92, 0.95 and 0.98, respectively. Likewise, seed yield of fennel was also directly correlated with it attributing characters; number of umbel and number of umbellates $plant^{-1}$ bears r^2 value 1.0 and 0.97, respectively. This might be due to the fact that higher growth parameters contributed towards more of yield attributing characters resultant more yield with applied N. Somewhat similar findings were also made by Saadul (2000) and Rai *et al.* (2002).

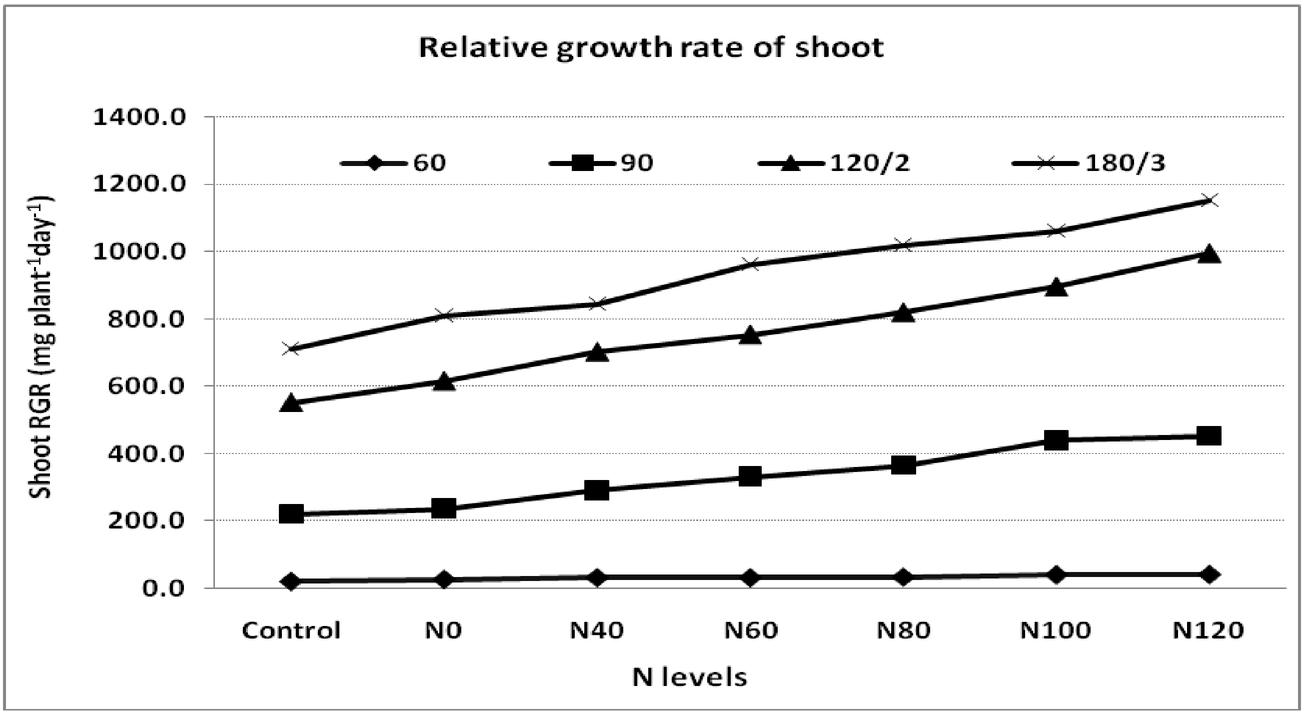
Fig.1. Relative growth rate of fennel root with N levels



Relative growth rate of root

At the age of 60 days relative root growth rate of fennel was only higher at alternative levels of N input (Fig. 1). However, it was only higher at N_{100} and N_{120} when crop attain the age of 90 and 180 day. Relative growth at 120 days was also higher at alternate levels of N except 40 to 80 kg of applied N. The relative growth rate of root was higher exponentially with time which indicates that fennel root remains in active phase even at maturity of crop (Fig.3). Relative growth rate of root with nitrogen levels slacked at early growth stage, while its response to higher level of nitrogen was distinctively higher, and hence at the age of 90 to 180 days was nearer to linearity. This might be due to annuals may have been able to more fully exploit the soil N pool under N-limiting conditions by creating more root surface area within per unit of root biomass and thus experiences a less severe reduction in RGR (Ryser and Lambers 1995). Variations in root growth and distribution in the soil profile among crops can lead to differences in water and nutrient uptake by roots. Roots that grow near water and nutrient availability are usually dense, have large diameter, and are active in growth and resource uptake (Pierret *et al.*, 2007). Only 10–30% of the total root length of a given root system, however, is actively involved in water and nutrient uptake (Robinson, 1991).In fenugreek, relative growth rate (RGR) of root and shoot was more with lime application and it was highest at the age of 51-75 days followed by 76-120 days and 10-50 days, respectively (Aishwath *et al.*, 2016).

Fig.2. Relative growth rate of fennel shoot with N levels



Relative growth rate of shoot

Relative growth rate of shoot was significantly influenced by N at 60 and 90 days (Fig. 2). However no statistical variation was observed within the treatments. Relative growth rate of shoot was increased with each successive levels of N at the 120 and 180 days, which indicated that this was the most active growth period of fennel crop. Relative growth rate of shoot with nitrogen levels slacked at early growth stage, while its response to higher level of nitrogen was distinctively higher, and hence at the age of 90 to 180 days was nearer to linearity.

Fig.3. Irrespective of treatments, relative growth rate of fennel root with time

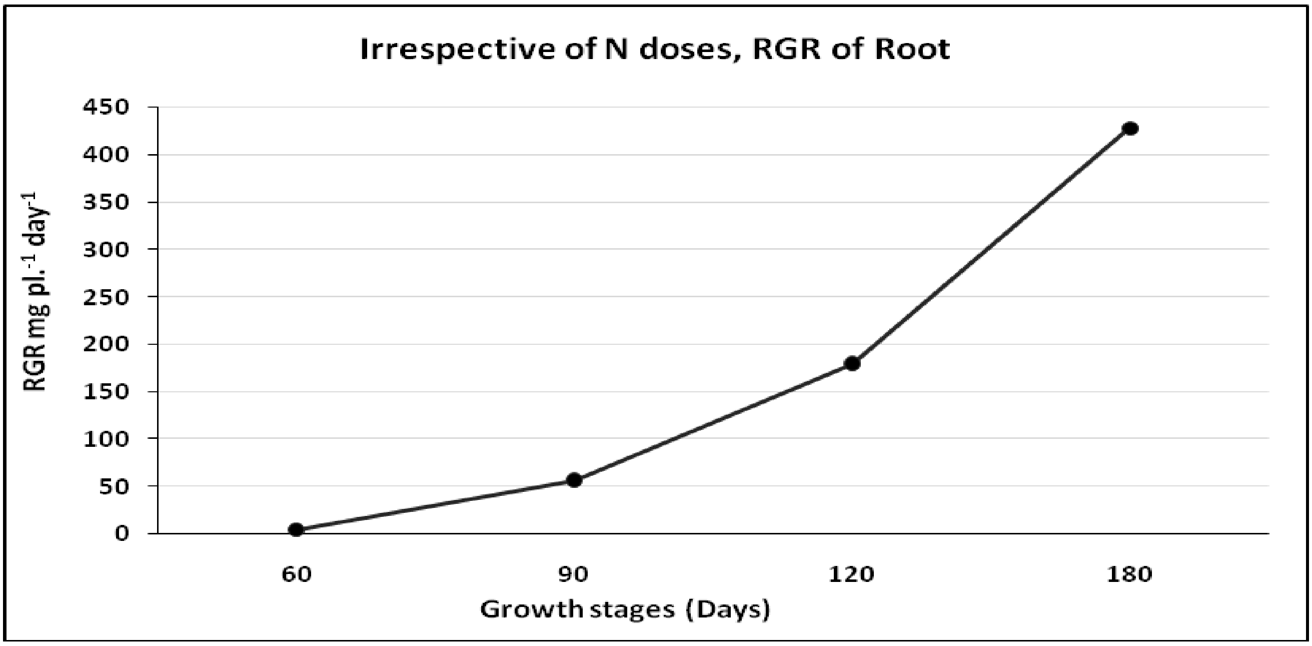
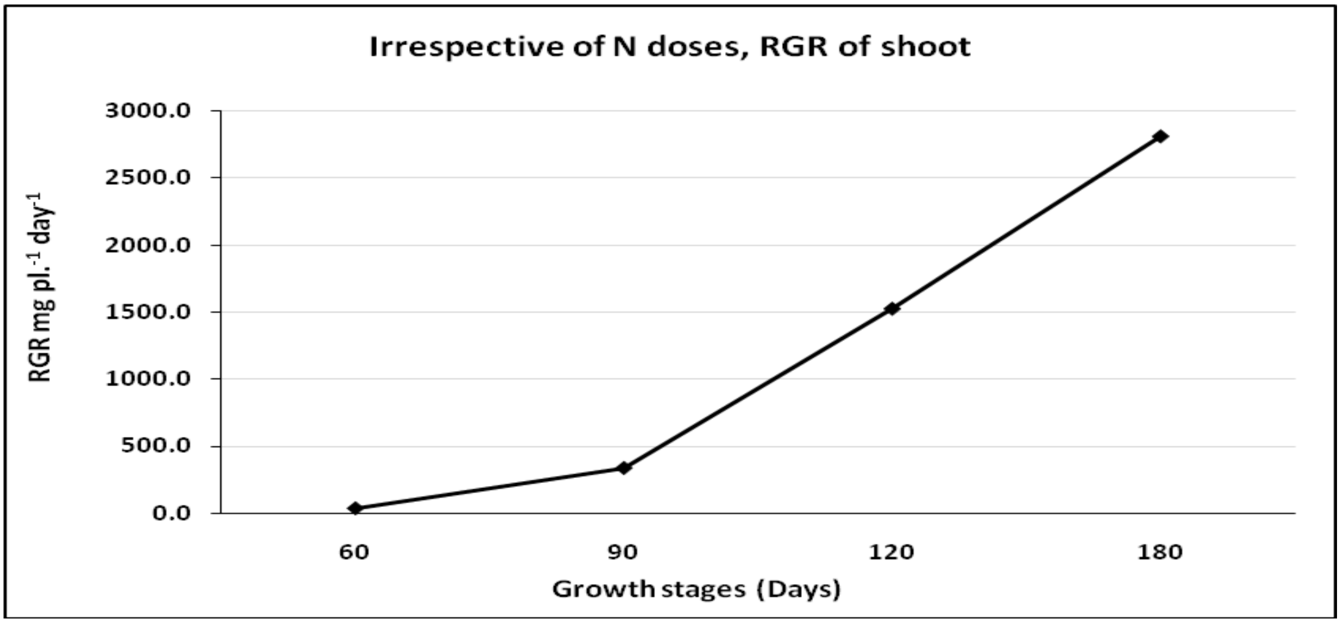


Fig.4. Irrespective of treatments, Relative growth rate of shoot with time



Irrespective of treatments, relative growth rate of shoot was linear beyond the age of 90 days (Fig.4) which reflects that nitrogen boosts the crop growth with greater impact during later growth stage of crop. Somewhat similar findings were also made by Walker *et al.* (2001)in lettuce (*Lactucasativa*) where RGR was dependent with available nitrate and its uptake. This is because of nitrogen is universally deficient nutrient. The most visible response was increased shoot growth in comparison to root at 120 days. These responses have led to the notion that nitrogen stimulates top growth at the expense of root growth stimulated by phosphorus (Bernatzky, 1978; British Standards Institute,1989; National Arborist Association, 1987; Neely and Himlick, 1987; Patch *et al.* 1984; Pironeet *al.* 1988; Tattar, 1989).Phonological stages of fennel has greater impact on relative growth rate (RGR) than N input (Fig.5).

Fig.5. Comparison of relative growth rate of fennel with both time and N input

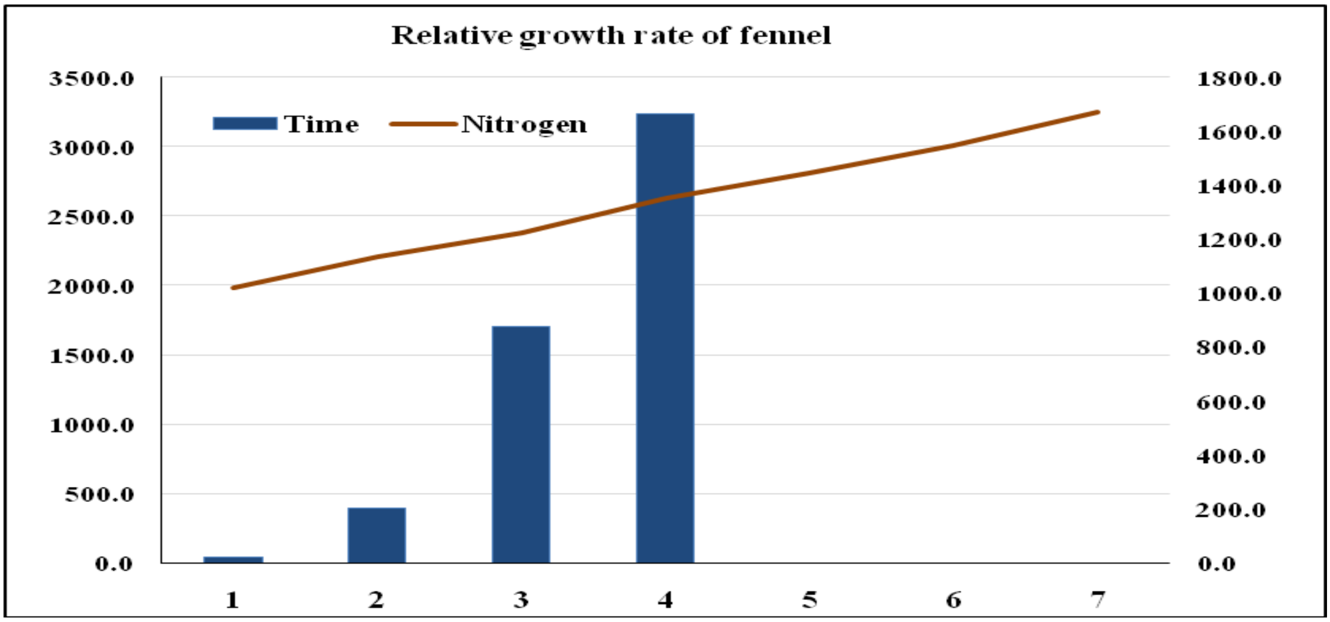
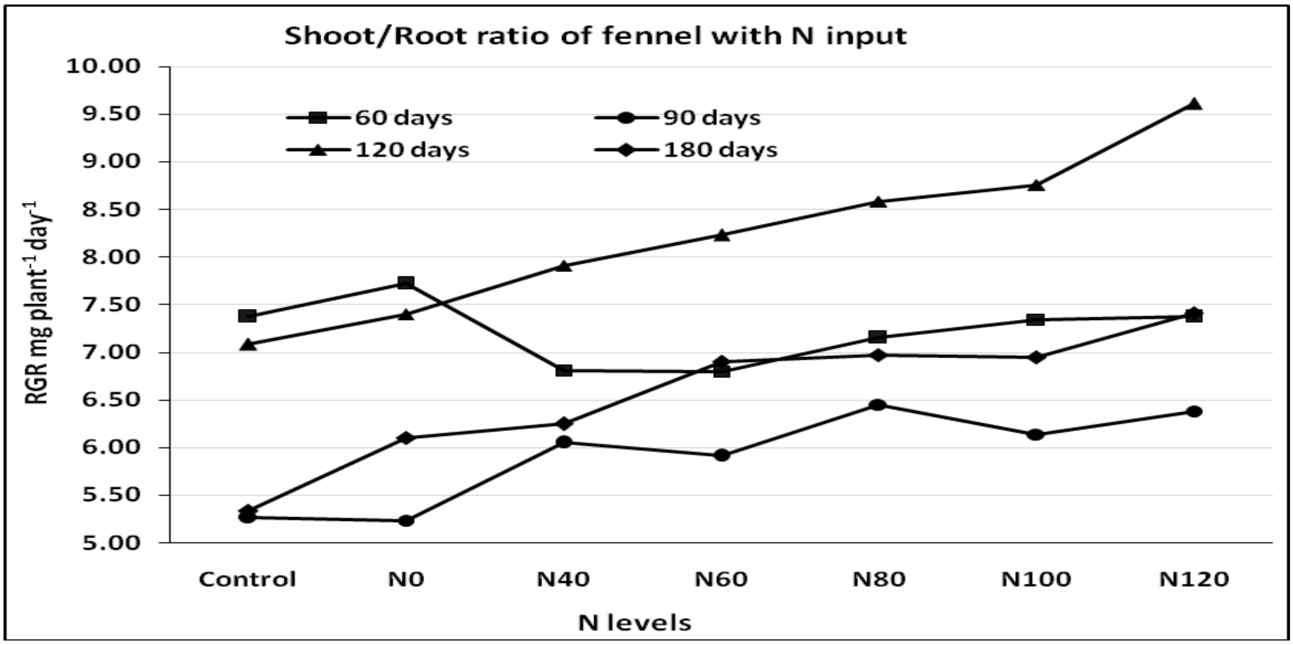


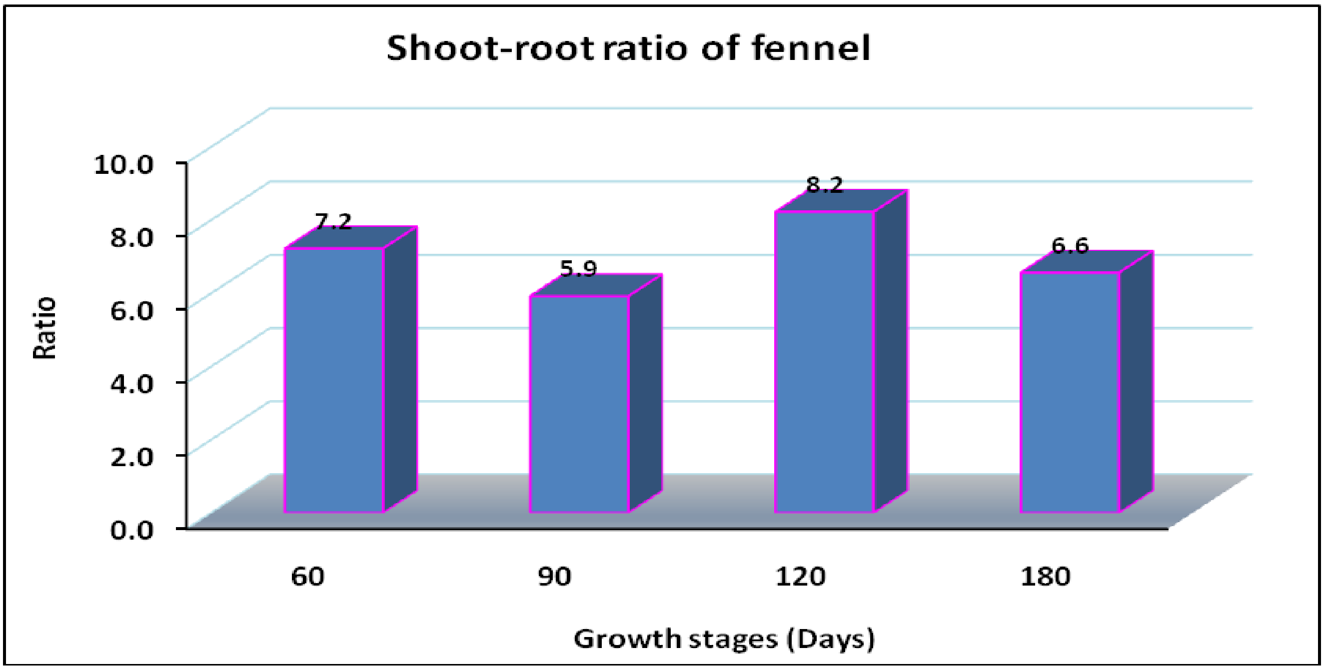
Fig.6. Shoot/root ratio of fennel with N levels



Shoot-Root ratio

Shoot-root ratio was not influenced by doses of N at 60 and 90 days age of fennel, whereas shoot-root ratio was higher at their alternate levels except middle levels at 120 days (Fig. 6). Contrast to it, shoot-root ratio was only higher at middle to lower levels of applied N and was at par with higher levels of N. Relative growth rate of root was much slower than the relative shoot growth particularly at later stages. This is because of carbon assimilation in root and shoot at various phonological stages of crop. Based on the shoot-root ratio, it could be inferred that shoot growth was higher at 60 and 120 days, however it was sluggish at 90 and 180 days or senescence.

Fig.7. Irrespective of treatments, shoot-root ratio at various growth stages



The trend of shoot-root ratio increased with increasing levels of nitrogen except 60 days of age. Shoot-root ratio tend to increase under N limited conditions than graded levels of applied N. This might be due to the fact that limited N supplies greatly affect the root growth than the shoot growth. Widest shoot-root ratio was observed at 120 days might be due to highest biomass accumulation in areal part at that stage (Fig.7).Wide shoot-root ration with N supply in smooth-brome grass was observed by Power (1988). Besides that there are other reports for many higher plant species like pea, bean and wheat also showed wide gap in shoot-root ratio due to increased N supply (Andrews 1993).

Conclusions

Growth, yield and their parameters of fennel were higher with increased doses of nitrogen which was around 1.5 times higher with 120 kg of N. Seed yield, number of umbel and number of umbellates were highly correlated with N levels. Likewise, seed yield of fennel was directly correlated with number of umbel and number of umbellates plant^{-1}. Relative Growth Rate (RGR) of fennel was very slow up to 90 days there after it increased linearly up to the age of 180 days or maturity. Nitrogen boosted the RGR and shoot-root ratio with their higher input than lower one. The relative growth rate of root was higher exponentially with time which indicates that fennel roots remain in active phase even at maturity of crop. Based on these growth kinetics/phenological parameters, fennel is an 'Herbaceous perennial bushy' (aerial part wither/dies in scorching summer and re-green during autumn) plant rather mentioned in the most of literature as 'perennial plant grown as an annual crop'. Due to slower growth up to 90 days, it can be fitted well in relay cropping which can increase cropping intensity in per unit time and space. Being a long duration crop, time had greater impact on RGR then N input.

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