Correlation Study between Growth Parameters, Yield and Oil Quality of *Anethum graveolens* Linn.

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Rathore *et al.*: Correlation Study of *Anethum graveolens* L

***Anethum graveolens* Linn is an important aromatic medicinal herb from the *Apiaceae* family. Seeds and leaves of this plant are the main parts that are being used. The main components obtained from its essential oil are carvone, limonene, dihydrocarvone, phellandrene and dillapiole. In order to study the correlation relation between growth attributes, yield components, yield and oil quality of European dill 2 y field cum laboratory experiments was carried out in N.E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand). The treatments were four cumulative pan evaporation levels of irrigation (50, 100, 150 and 200 mm) as main plots and three fertility levels (0, 15 and 30 t FYM ha^{-1}) in sub plots in a factorial randomized block design with three replications. After harvesting of crop, seed yield was recorded and seeds were analysed for the oil quality. Two years data revealed that successive levels of irrigation and farmyard manure application increased the yields and treatment combination $I_{100}F_{30}$ significantly increased the growth, seed and oil yield and oil quality of *Anethum graveolens* Linn. Simple correlation analysis showed a significant and positive relation among almost all the growth parameters (plant height, number of branches, dry matter accumulation) of *Anethum graveolens* Linn. with yield and yield attributes i.e., number of umbels and umbellets on different branches, number of fruits per umbel and test weight. Oil content was found to be non-significantly but positively associated with seed yield while a highly significant positive correlation was observed between seed and oil yield. In case of oil quality, carvone had a significant and negative correlation with dillapiole however it was positively associated with oil content and oil yield.**

Key words: Correlation, European dill, *Anethum graveolens*, irrigation, FYM, yield and oil content, carvone, dillapiole

In recent decades, the scope of cultivation of medicinal herbs especially in developed countries is increasing due to the side-effects of chemical medications, environmental restrictions and gradual tendency of majority people to go for herb therapy. European Dill (*Anethum graveolens* Linn.) is an herbaceous plant belonging to the family of *Umbelliferae (Apiaceae)*. Dill has a very long history of usage dating back to more than 2000 y, and presently it is cultivated all over the world, in India, Iran, China, South Europe, Bulgaria and Estonia.

In traditional medicine system, *Anethum graveolens* is used for digestion problems, liver problems as well as in kidney diseases[1].

Fresh and dried leaves are used as a carminative, stomachic, antispasmodic herb in Indian medicine. They are also used for the prevention and treatment of diseases of the gastrointestinal tract and urinary tract.

According to Setorki *et al*., 2013[2], *A. graveolens* can reduce the negative effects of postprandial cholesterol rich diet and an effective choice for preventing some of the risk factors of atherosclerosis. The seeds (fruits) are used for many medicinal purposes as stomachic, antipyretic, carminative, sedative, lactagogue, antispasmodic, stimulant, antidysenteric, diuretic, laxative, anthelmintic and used to treat gastric ulcers, abdominal pain, eye diseases, urinary pains, neuralgia,

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bronchial asthma, haemorrhoids, genital ulcers and dysmenorrhoea[3,4]. It is also used for treatment of griping pains[5]. Dried and ripe fruits are used in pediatric complaints, such as flatulence and weak digestion[6]. Essential oil of dill seed has been investigated in connection with their antimicrobial, antiseptic and exhibits anticarcinogenic activity and antioxidant[7].

The herb (0.5 to 1.2 %) and seed (2.5 to 3.5 %) of this crop contain an essential oil popularly known as dill oil. The most important essential oil compounds from this plant are d-carvone and phellandrene, whereas the most important compounds from the fully grown seeds are carvone, limonene dihydrocarvone, phellandrene and dillapiole. European cultivar is superior to all cultivars for the best volatile oil content as well quality[8]. Seed oil is considered to be of good quality due to presence of more carvone and least dillapiole contents. In medicinal plants, the content of metabolite is economically more important than the crude yield of the plant part containing the metabolite[9].

The price of European dill seed oil varies between Rs. 1500-2000/kg[10]. Owing to its diversified uses, commercial value of the essential oils from the fruits (seeds) of dill is a good source of foreign exchange and, growers are looking it as a new cash crop. So, there is need to raise the productivity of dill crop by adopting scientific cultivation methods.

However, the goal of higher production and good quality essential oil can be achieved with judicious water management and good nutrient supply. Therefore, the present investigation was carried out to study the effect of irrigation scheduling and farmyard manure (FYM) nutrition on growth, yield components and yield of European dill as well on the quality of dill oil.

MATERIALS AND METHODS

A field experiment was conducted for 2 y at N.E. Borlaug Crop Research Centre and laboratory studies were undertaken in the department of Agronomy, College of Agriculture, respectively at G. B. Pant University of Agriculture and Technology, Pantnagar, U. S. Nagar, Uttarakhand, India. Pantnagar is located at 29° N latitude, 79.3° E longitude and at an altitude of 243.8 metres above mean sea level in Tarai region of Uttarakhand which falls in humid subtropical zone. The soil of the experimental site was fine sandy loam in texture and the surface (0-15 cm) soil was rich in organic carbon content, low in available nitrogen, medium in available phosphorus and potassium and it was neutral in reaction. The climate of Pantnagar is subtropical-sub-humid with extremes of weather conditions, having hot and dry summers and cold winters.

The treatments comprising 4 levels of irrigation scheduled at 50 (I_{50}), 100 (I_{100}), 150 (I_{150}) and 200 (I_{200}) mm cumulative pan evaporation (CPE) and 3 levels of soil fertility viz, 0 (F_0), 15 (F_{15}) and 30 (F_{30}) t FYM ha^{-1}, which were evaluated in factorial randomized block design with three replications. The field was irrigated 3 w before sowing to maintain moisture and facilitate field operations. The field was prepared by one ploughing and two cross harrowing followed by levelling. The crop was sown during two consecutive winter seasons (known as rabi season) in mo of December and harvested in the mo of May. The net plot size was 2.4 m×2.4 m. Well decomposed and pulverized farmyard manure (FYM) broadcasted carefully in different amounts in each plot as per treatments 2 d before sowing and mixed uniformly and thoroughly by digging with the help of spade. The crop was raised by direct seeding at a seed rate of 5 kg ha^{-1}. Seeds were pre-soaked in water and kept moist for 48 h before sowing and sown in 3-4 cm deep furrows with maintaining the spacing of 40 cm (row to row)×30 cm (plant to plant) in each plot. Extra seedlings were thinned out at 20 d after sowing to obtain constant number of plants in each row of all the plots. Wherever required, gap filling was done using the uprooted seedlings from the same plot during thinning.

The experimental field had a good tube well facility so scheduling of irrigation to the crop was not a problem. One common irrigation was given in each plot 25 d after sowing for proper crop establishment. Post-sowing irrigations of 60 mm depth were applied as per treatment details. Irrigation treatments were executed by providing irrigation channels between the plots. Subsequent irrigation treatments were scheduled based on CPE data. Irrigation water was measured with the help of Parshall flume under free flow conditions fixed in the irrigation channel to provide water upto 60 mm depth of soil at each irrigation. Depending upon rainfall, number of irrigation was applied as per treatments. Treatment combinations are detailed below:

For the observations on growth and yield attributes, two rows from left side of each plot were used for destructive sampling and five plants were randomly selected from net plot area and tagged before starting observation. After proper sun drying, the umbels were threshed manually. Thereafter, the seeds were collected, cleaned and weighed. Seed yield was expressed in q ha^{-1}. The crop quality was judged by extracting oil from seeds and active principles present in oil. For obtaining seed oil, water distillation method using Clevenger's type glass distillation apparatus was used. Immediate after crop harvesting and threshing, essential oil was distilled from fresh seeds. Distillation process for each sample was continued for 3 h. The essential oil content was calculated using formula:

Essential oil content (% volume by weight basis)=Quantity of Essential oil (ml)/Seed weight (g)×100

For determination of oil constituents, filtered dehydrated essential oil samples were analyzed by using Gas-liquid chromatography. The Retardation Factor (RF) value of pure carvone was obtained by injecting 0.2 μ ml of pure liquid carvone (standard) diluted 4 times with ethanol with micro-syringe. The area percentage obtained in chromatographs was taken as percentage of the major constituents' viz., carvone, limonene and dillapiole.

Seed, oil and carvone yield was calculated by using following formulae: **Seed yield** (q/ha)=seed yield (g) per plot/5.76×10, **Oil yield** (kg/ha)=seed yield (kg/ha)×Oil content in seed (%)×Specific gravity* of seed/100, *specific gravity of essential oil of *Anethum graveolens* is: (0.87 g/cc), (iii) **Carvone yield** (kg/ha)=Oil yield (kg/ha)×Carvone content in seed oil (%)/100.

The statistical analysis[11] of the data was done by following the standard procedures. The correlation matrix was prepared with the software IBM SPSS statistics V22[12].

RESULTS AND DISCUSSION

Seed, oil and carvone yields of fresh seeds during both the years were found to be the highest under 100 mm CPE level while during 2nd y, being at par with 50 mm CPE level caused significantly more seed yield compared to 150 and 200 mm CPE levels of scheduling irrigation (Table 1). Increasing levels of FYM caused significant increase in seed, oil and carvone yield during 1st y while during 2nd y application of 30 tonnes FYM/ha caused significantly more yield compared to 0 and 15 tonnes FYM/ha.

Higher yield at 100 mm CPE level might be because of higher dry matter accumulation which resulted in enhanced growth characters and yield attributes by providing reserve food for reproductive phase thus the number of fruits and seed weight were also found to be higher. Farmyard manure at its higher levels was expected to provide about 75, 37.5 and 75 kg N, P, and K/ha through 15 tonnes FYM/ha and 150, 75 and 150 kg N, P, and K/ha at 30 tonnes FYM/ha levels, respectively and was expected to meet the total nutrients requirement of the crop. In addition, it provided all micronutrients which are essential for plant growth and secondary metabolites synthesis and also activate the microbial growth which helps in making nutrients more available[13].

Interestingly, the oil content in seeds was found to be significantly higher when crop was irrigated at 200 mm CPE compared to the remaining irrigation levels during 1st y though the differences disappeared during 2nd y, where irrigating the crop at 150 mm CPE level gave the highest oil content (Table 2). Water stress imposed by restricting the number of irrigations increased the percentages of volatile oils in parsley and fennel[14]. It has been also studied by Kaur and Arora[15] that essential oil plays an important role in mechanism of drought resistance via reduction in transpiration. Ezz *et al*.,[16], found the stress conditions accelerated the biosynthesis of essential oils. The 30 tonnes/ha FYM application caused significantly more oil content in seeds compared to 0 and 15 tonnes/ha FYM levels during both the years.

Increase in yield due to adequate amount of irrigation and FYM application could be ascribed to good availability and better utilization of nutrients, increased synthesis of carbohydrates leading to good vegetative and reproductive growth[17].

Coefficient of correlation between various growth parameters and yield attributes are presented in Table 3.

Various growth parameters and yield attributes were found to be significantly and positively correlated with each other during both the years however the positive correlation was found between plant height and dry

TABLE 1: TREATMENT DETAILS

S. No.	Treatment combinations	Treatment notation
	50 mm CPE without FYM	$I_{50}\ F_0$
	50 mm CPE with 15 t ha^{-1} FYM	$I_{50}\ F_{15}$
	50 mm CPE with 30 t ha^{-1} FYM	$I_{50}\ F_{30}$
	100 mm CPE without FYM	$I_{100}\ F_0$
	100 mm CPE with 15 t ha^{-1} FYM	$I_{100}\ F_{15}$
	100 mm CPE with 30 t ha^{-1} FYM	$I_{100}\ F_{30}$
	150 mm CPE without FYM	$I_{150}\ F_0$
	150 mm CPE with 15 t ha^{-1} FYM	$I_{150}\ F_{15}$
	150 mm CPE with 30 t ha^{-1} FYM	$I_{150}\ F_{30}$
	200 mm CPE without FYM	$I_{200}\ F_0$
	200 mm CPE with 15 t ha^{-1} FYM	$I_{200}\ F_{15}$
	200 mm CPE with 30 t ha^{-1} FYM	$I_{200}\ F_{30}$

matter accumulation; leaf volume and dry matter accumulation; dry matter accumulation with umbellets per umbel on main shoot, umbellets per umbel on primary branches, umbellets per umbel on secondary branches, umbellets per umbel on tertiary branches, number of seeds per umbel on primary branches, number of seeds per umbel on secondary branches, number of seeds per umbel on tertiary branches and seed weight during 1st y. Higher values for growth parameters correlated well with yield attributes to the crops viz. fennel, carrot, cumin and other umbelliferous rabi crops have also been reported by Sharma and Prasad, Batra and Kallo, Patel *et al*., Singh and Mahey, Jangir and Singh, Milia *et al*. and Singh *et al*.[18-24]. The higher dry matter

TABLE 2: YIELD (kg ha^{-1}) OF FRESH SEED AS INFLUENCED BY THE DIFFERENT TREATMENTS

Treatments	Fresh seed					
	I year			II Year		
	Seed yield (kg ha^{-1})	Oil yield (kg ha^{-1})	Carvone yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Oil yield (kg ha^{-1})	Carvone yield (kg ha^{-1})
Irrigation levels (mm CPE)						
50	10.88	22.70	18.91	9.75	26.72	19.73
100	11.71	25.87	21.66	11.44	31.17	23.15
150	9.95	21.07	17.58	7.45	21.30	15.68
200	9.12	20.67	17.37	8.02	22.95	17.11
SEm±	0.21	0.59	0.49	0.71	2.25	1.67
C.D. at 5 %	0.63	1.74	1.45	2.08	6.61	4.90
FYM levels (t ha^{-1})						
0	9.32	15.77	12.96	8.42	21.55	15.69
15	10.66	23.19	19.52	8.14	22.37	16.71
30	11.26	28.78	24.16	10.95	32.69	24.34
SEm±	0.18	0.51	0.43	0.61	1.95	1.43
C.D. at 5 %	0.54	1.51	1.26	1.80	5.72	4.24

TABLE 3: CORRELATION BETWEEN GROWTH PARAMETERS AND YIELD ATTRIBUTES

Parameters	Y	LV	DMA	UL/MS	UL/PB	UL/SB	UL/TB	NS/MS	NS/PB	NS/SB	NS/TB	SW
PH	I	0.701*	0.285	0.989*	0.986*	0.969*	0.976*	0.980*	0.972*	0.983*	0.987*	0.980*
	II	0.985*	0.906*	0.983*	0.987*	0.972*	0.977*	0.991*	0.989*	0.994*	0.967*	0.991*
LV	I	-	0.158	0.755*	0.718*	0.711*	0.762*	0.773*	0.719*	0.770*	0.758*	0.735*
	II	-	0.955*	0.995*	0.960*	0.989*	0.987*	0.991*	0.971*	0.974*	0.989*	0.979*
DMA	I	-	-	0.310	0.275	0.310	0.377	0.712*	0.332	0.343	0.367	0.336
	II	-	-	0.955*	0.864*	0.971*	0.936*	0.931*	0.891*	0.885*	0.968*	0.897*
UL/MS	I	-	-	-	0.969*	0.956*	0.964*	0.970*	0.964*	0.980*	0.985*	0.972*
	II	-	-	-	0.968*	0.994*	0.994*	0.994*	0.980*	0.974*	0.995*	0.981*
UL/PB	I	-	-	-	-	0.993*	0.983*	0.985*	0.986*	0.985*	0.985*	0.991*
	II	-	-	-	-	0.954*	0.968*	0.981*	0.996*	0.994*	0.947*	0.987*
UL/SB	I	-	-	-	-	-	0.975*	0.973*	0.991*	0.977*	0.980*	0.992*
	II	-	-	-	-	-	0.987*	0.987*	0.968*	0.961*	0.964*	0.962*
UL/TB	I	-	-	-	-	-	-	0.980*	0.986*	0.994*	0.993*	0.989*
	II	-	-	-	-	-	-	0.992*	0.979*	0.968*	0.993*	0.974*
NS/MS	I	-	-	-	-	-	-	-	0.974*	0.978*	0.978*	0.978*
	II	-	-	-	-	-	-	-	0.990*	0.985*	0.986*	0.988*
NS/PB	I	-	-	-	-	-	-	-	-	0.989*	0.988*	0.977*
	II	-	-	-	-	-	-	-	-	0.993*	0.964*	0.992*
NS/SB	I		-	-	-	-	-	-	-	-	0.996*	0.993*
	II	-	-	-	-	-	-	-	-	-	0.952*	0.993*
NS/TB	I	-	-	-	-	-	-	-	-	-	-	0.993*
	II	-	-	-	-	-	-	-	-	-	-	0.961*

[PH: Plant height (cm), DMA: Dry matter accumulation (g m^{-2}), LV: Leaf volume (m^{-3}), MS: Main shoot, PB: Primary branches, SB: Secondary branches, TB: Tertiary branches, U: Umbel, UL: Umbellets, NS: Number of seeds, SW: 1000 Seed weight (g)]
*Significant at 5 % level of probability; t value at 10 d.f. (n-2): 0.576.

accumulation towards maturity accelerate reproductive phase and seed formation which might have caused more number of fruits per umbel ultimately resulting in more seed yield[25].

The higher dry matter accumulation enhanced yield attributes by providing reserve food for reproductive phase thus, the number of umbels on different branches, number of umbellets per umbel, number of fruits per umbel and 1000 seed weight were found higher. More number of primary, secondary and tertiary branches produced more number of umbels, number of umbellets per umbel, fruits per umbel and test weight. All growth parameters were found to be positively associated with seed yield during both the years (Table 4).

A significant and positive correlation between plant height and various branches, dry matter accumulation, leaf volume was found during both the years. The seed yield was found to be positively correlated with plant height; however significant association was noticed during 1st y. Primary branches were also found to be significantly positively correlated with secondary branches, leaf volume and seed yield during both the years and with tertiary branches and leaf volume during 2nd y. Secondary branches had significant positive correlation with tertiary branches and dry matter accumulation during 2nd y and during both the years with leaf volume and seed yield. Though, tertiary branches had positive correlation with dry matter accumulation, leaf volume and seed yield but it was significant only during 2nd y. Dry matter accumulation was significantly and positively associated with seed yield during 2nd y while during 1st y this positive association was non-significant. Leaf volume and seed yield were found to be significantly positively associated with each other during both the years. Also, studies by Escalante Estrada *et al*.,[26] and Zhao *et al*.[27] indicated that the production of the dry matter or biomasses of any plant is determined by the higher value of LAD (leaf area duration) and NAR (net assimilation rate). Decrease in LAD and NAR was found to be strongly correlated with a decrease in biomass[28].

Various yield attributes were also found to be positively associated with seed yield and with each other during both the years (Table 5).

Umbellets per umbel and seeds per umbel on main shoot and different branches were found to be significantly positively associated with each other, with 1000 seed weight and with seed yield during both the years.

The data pertaining to correlation coefficients between oil content, seed, oil and carvone yield are presented in Table 6. The correlation coefficients for the different variables assessed for seed yield were observed to be positively correlated with oil content and oil yield.

Oil content was found to be non-significantly positively associated with seed yield during both the years, and oil yield during 2nd y. A strong significant positive correlation (r=0.967 at p=0.05) was observed between seed and oil yield during both the years.

As oil yield is the function of seed yield and oil content. In spite of, comparatively less oil content in seeds obtained, the oil yield was found more because of increased seed yield.

Limonene was found to be negatively correlated with carvone, dillapiole, oil content and oil yield during both the years (Table 7).

TABLE 4: CORRELATION BETWEEN GROWTH PARAMETERS AND SEED YIELD

Parameters	Y	Primary branches	Secondary branches	Tertiary branches	Dry matter accumulation (g m^{-2})	Leaf volume (m^{-3})	Seed yield (q ha^{-1})
Plant Height (cm)	I	0.940*	0.944*	0.597*	0.285	0.701*	0.989*
	II	0.869*	0.963*	0.956*	0.906*	0.985*	0.560
Primary branches	I	-	0.877*	0.447	0.226	0.801*	0.945*
	II	-	0.868*	0.871*	0.788*	0.853*	0.717*
Secondary branches	I	-	-	0.483	0.280	0.786*	0.969*
	II	-	-	0.962*	0.941*	0.971*	0.652*
Tertiary branches	I	-	-	-	0.039	0.371	0.537
	II	-	-	-	0.974*	0.985*	0.668*
Dry matter accumulation (g m^{-2})	I	-	-	-	-	0.158	0.320
	II	-	-	-	-	0.955*	0.706*
Leaf volume (m^{-3})	I	-	-	-	-	-	0.766*
	II	-	-	-	-	-	0.631*

*Significant at 5 % level of probability; t value at 10 d.f. (n-2): 0.576

TABLE 5: CORRELATION BETWEEN YIELD ATTRIBUTES AND SEED YIELD

Parameters	Y	UL/U on PB	UL/U on SB	UL/U on TB	NS/U on MS	NS/U on PB	NS/U on SB	NS/U on TB	Seed Weight (g)	Seed Yield (q ha^{-1})
UL/U on MS	I	0.969*	0.959*	0.964*	0.970*	0.964*	0.980*	0.985*	0.972*	0.993*
	II	0.968*	0.994*	0.994*	0.994*	0.980*	0.974*	0.995*	0.981*	0.655*
UL/U on PB	I	-	0.993*	0.983*	0.985*	0.986*	0.985*	0.985*	0.991*	0.965*
	II	-	0.954*	0.968*	0.981*	0.996*	0.994*	0.947*	0.987*	0.560
UL/U on SB	I	-	-	0.975*	0.973*	0.991*	0.977*	0.980*	0.992*	0.945*
	II	-	-	0.987*	0.987*	0.968*	0.961*	0.994*	0.962*	0.674*
UL/U on TB	I	-	-	-	0.980*	0.986*	0.994*	0.993*	0.989*	0.971*
	II	-	-	-	0.992*	0.979*	0.968*	0.993*	0.974*	0.622*
NS/U on MS	I	-	-	-	-	0.974*	0.978*	0.978*	0.978*	0.967*
	II	-	-	-	-	0.990*	0.985*	0.986*	0.988*	0.629*
NS/U on PB	I	-	-	-	-	-	0.989*	0.988*	0.997*	0.953*
	II	-	-	-	-	-	0.993*	0.964*	0.992*	0.586*
NS/U on SB	I	-	-	-	-	-	-	0.996*	0.993*	0.981*
	II	-	-	-	-	-	-	0.952*	0.993*	0.572
NS/U on TB	I	-	-	-	-	-	-	-	0.993*	0.985*
	II	-	-	-	-	-	-	-	0.961*	0.647*
Seed Weight (g)	I	-	-	-	-	-	-	-	-	0.967*
	II	-	-	-	-	-	-	-	-	0.602*

[MS: Main shoot, PB: Primary branches, SB: Secondary branches, TB: Tertiary branches, U: Umbel, UL: Umbellets, NS: Number of seeds]
*Significant at 5 % level of probability; t value at 10 d.f. (n-2): 0.576

TABLE 6: CORRELATION BETWEEN OIL CONTENT, SEED AND OIL YIELD

Parameters	Year	Seed yield (q ha^{-1})	Oil yield (Kg ha^{-1})
Oil content (%)	I	0.505	0.890*
	II	0.293	0.513
Seed yield (q ha^{-1})	I	-	0.837*
	II	-	0.967*

*Significant at 5 % level of probability; t value at 10 d.f. (n-2): 0.576

TABLE 7: CORRELATION BETWEEN OIL CONTENT, CONSTITUENTS AND OIL YIELD OF FRESH SEEDS

Parameters	Year	Limonene (%)	Carvone (%)	Dillapiole (%)	Oil content (%)	Oil yield (kg ha^{-1})
Limonene (%)	I year	-	-0.528	-0.065	-0.240	-0.031
	II year	-	-0.528	-0.066	-0.075	-0.203
Carvone (%)	I year	-	-	-0.728*	0.798*	0.670*
	II year	-	-	-0.728*	0.442	0.231
Dillapiole (%)	I year	-	-	-	-0.752*	-0.777*
	II year	-	-	-	-0.405	-0.580*
Oil content (%)	I year	-	-	-	-	0.890*
	II year	-	-	-	-	0.513

*Significant at 5 % level of probability; t value at 10 d.f. (n-2): 0.576

Carvone was found to be positively correlated with oil content and oil yield during both the years however it was significant only during 1 y. This study is also supported by Yassen and Khalid[29] who observed that as volatile oil improved the some of the main constituents of essential oil in onion were also improved.

Dillapiole was negatively correlated with oil content and oil yield, however, the association was significant between dillapiole and oil content during 1 y and between dillapiole and oil yield during both the years. Oil content and oil yield were positively correlated during both the years, however, it was significant during 1 y.

The quality of dill seed oil is determined by its constituents. Higher carvone and limonene contents and negligible dillapiole content in oil has been reported to be of good quality[30]. Sandermann and Bruns[31] reported that limonene is an intermediate in the biosynthesis of carvone as depicted in fig. 1.

The finding of the present study that limonene content was negatively correlated with carvone content was strongly supported by observation of Jana and Shekhawat[32] that carvone increased at the expense of limonene and vice versa (fig. 2).

The dillapiole is considered to be toxic to human consumption at more than 5 % in essential oil and thus, quality of essential oil is considered better if dillapiole content in the oil varies between 0 to 5 %.

On the basis of results, it can be concluded that to get enhanced quantity as well quality of essential oil and improved production per unit area of *Anethum graveolens* L., crop must be irrigated at 100 mm CPE at 6 cm depth depends on rainfall and fertilized with 15-30 t FYM/ha. Also, overall growth and yield attributes had a strong correlation impact on plant biomass production influencing production, productivity and quality of *Anethum graveolens* L.

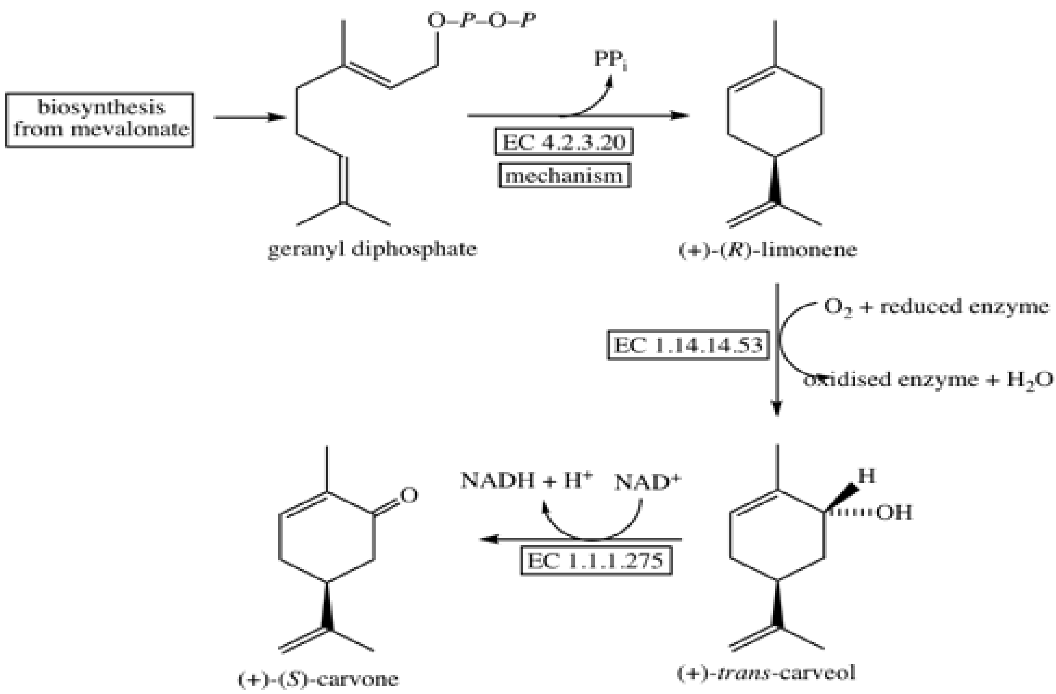

Fig. 1: Biosynthesis of carvone

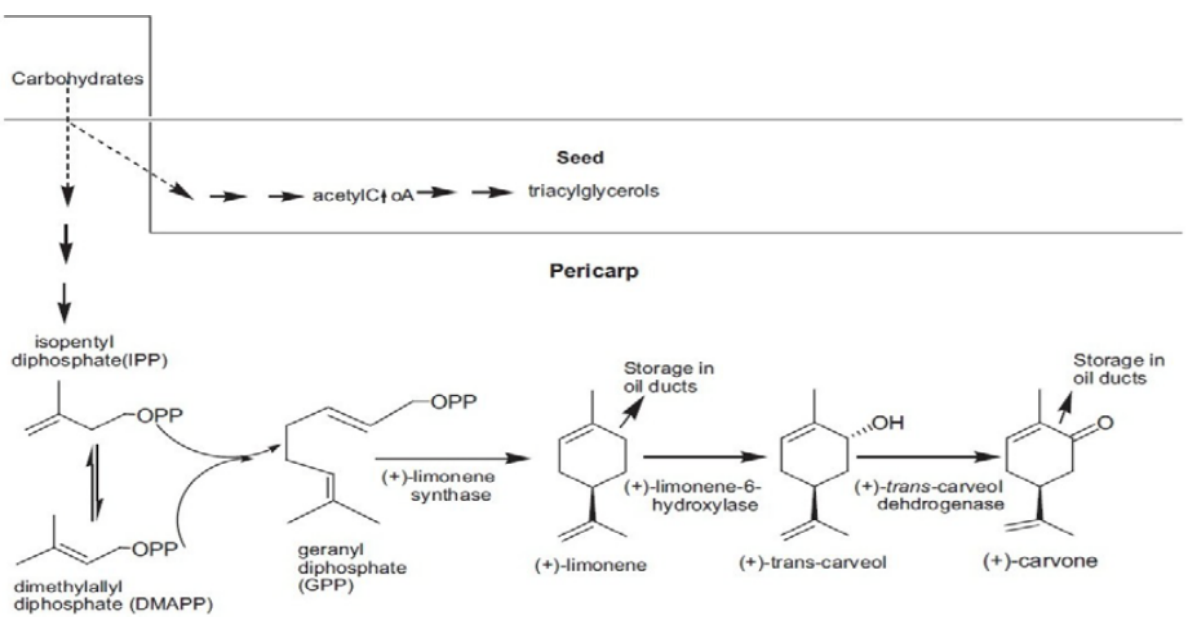

Fig. 2: Enzymatic pathway depicting synthesis of limonene and carvone in seeds of *Anethum graveolens*

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