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Effect of irrigation and fertigation levels through pulse drip irrigation on growth parameters of carrot (*Daucus carota* L.)

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Abstract
Water management is an important factor for sustainable agriculture development, since it is necessary to get a higher production per unit of applied water. This study aimed to determine the effect of different pulses, irrigation and fertigation levels through drip irrigation on growth parameters of carrot (*Daucus carota* L.), during the 2019-20 and 2020-2021 growing seasons in Dapoli, Konkan (MS). The irrigation water of 80, 100 and 120% of crop evapotranspiration (ETc) was applied through four pulses P_1, P_2, P_3 and P_4 with constant 30 minutes interval between each split. The water soluble fertilizer with rates 80, 100 and 120% of recommended dose of fertilizer (RDF) was applied through irrigation water. The study results revealed for average value of highest number of leaves, plant height and canopy diameter in P_4 (four) pulse number, I_2 (1.0 ETc) & I_3 (1.2 ETc) irrigation levels and F_3 (1.2 RDF) fertigation level. The maximum number of leaves found in treatment combinations P_4I_2, P_4F_3, F_3I_2 and $P_4I_3F_3$. Further, treatment combinations P_4I_2, P_4F_2, F_3I_2 and $P_4I_2F_3$ showed maximum plant height. The plant canopy diameter was observed maximum in P_4I_3, P_4F_2, F_3I_3 and $P_4I_3F_3$ treatment combinations.

Keywords: Pulse, irrigation, fertilizer, carrot and growth parameters

Introduction
The world's total water resources are estimated to be 136×10^6 Mha-m. This global water resources are comprises of 97.2% salt and 2.8% fresh water. The fresh water includes 2.2% surface and 0.6% groundwater. Further, it is estimated that, 0.01% (1.36×10^4 Mha-m) surface water and 0.25% (34×10^4 Mha-m) groundwater is available and can be economically extracted to use (Raghunath, 2006) [14]. The estimated available water in India is about 199.9 Mha-m out of which 112.3 Mha-m can be used. The amount of utilisable water comprises of 69 Mha-m and 43.3 Mha-m from surface and groundwater sources respectively. The demand of fresh water in India for domestic, irrigation, energy, industries and others is 4.26, 55.38, 2.13, 3.55 and 5.68 Mha-m respectively, which sums up to 71.0 Mha-m (Vohra & Franklin, 2021) [22].

The growing population and social-economic development of world increase demand of water resources day by day (Zapata y Segura, 1995) [24]. The pressure on water resources is expected to further increase as the requirements for food production and industrial needs go up in parallel with the country's rapidly growing population and its development (Webber *et al*., 2006) [23]. The economical water resources are limited through worldwide therefore it is an urgent need to identify and adopt efficient irrigation management strategies because agricultural sector accounts over 85% of worldwide water usage for irrigation (Zegbe *et al*., 2006) [25].

The pressurized irrigation systems such as sprinkler and drip can be used to decrease agricultural water demand by reducing water losses. Water savings can be achieved either by decreasing the frequency of irrigation events or by a systematic reduction of water for irrigation (Darwish *et al*., 2006) [5]. The application of irrigation water in stages or pulses rather than all at one time can save water by giving the media time to moisten from the first pulse of water thereby allowing it to absorb subsequent irrigation more readily and reducing the total amount of water required. For example, instead of irrigating 4 different areas for 1 hour each (four hours total), studies have revealed that by watering each area sequentially for 15 minute intervals and repeating this process twice reduces 25% water (Scott, 2000) [16]. Increase in irrigation frequency might provide desirable conditions for water movement in soil and for uptake by roots (Segal *et al*., 2000) [17].

The systems have undergone immense development in recent years and now allow the simple and accurate timing of irrigation events. The level of control includes the ability to "pulse" irrigation events to meet the needs of soils that have less than desirable infiltration rates, thus minimizing run off (Thompson, 2001) [19]. Continuous water application is associated with increased water percolation under root zone. Intermittent irrigation strategy based on discharge pulses followed by breaks could improve water management in the field and increase irrigation efficiency (Oron, 1981) [12].

Irrigation water and nutriens are the most important inputs which directly affects the plant growth development, yield and quality of produce. Application of fertilizers along-with irrigation water through drip is the most effective way of supplying nutrients to the plant roots. These inputs are effectively utilized by the plants as these are placed near crop root zone. The appropriate combination of water and nutrients is the very crucial for high yield and the quality of produce. Fertigation saves fertilizer as it permits applying fertilizer in small quantities at a time matching with the plants' nutrient need and avoids leaching of fertilizers. The nutrient consumption per unit area and fertilizer use efficiency is very low in India though it being the third largest producer and consumer of fertilizer in the world (Sathya *et al.*, 2008) [15]. The main reasons for low efficiency are the types of fertilizers used and the methods of application adopted by Indian peasants. Use of fertilizers in a balanced proportion and incorporating them through drip along irrigation water (fertigation) not only optimizes the water use but also increases the nutrient use efficiency. According to Solaimalai *et al*., (2005) [18], fertigation method gives higher nutrient use efficiency (90%) and conventional methods have only 40 to 60%.The excessive quantity of inorganic fertilizers add more base material to native soil due to which biological dynamics, water and environmental conditions changes in soil.

Water requirements of carrot crop ranges from 6000 to 9000 $m^3.ha^{-1}$ with an average pan evaporation of 6 to 7 $mm.d^{-1}$, depending mainly on the crop period, which lasts between 100 and 140 days (Villeneuve and Leteinturier, 1992) [21]. A study carried out on a carrot crop showed higher root production, total dry matter and water use efficiency with a water application level of 100% Epan (Prabhakar *et al*., 1991) [13]. Moreover, Gibberd *et al*. (2003) [8] studied water application in a carrot crop cultivated in sandy soils and determined that a higher marketable carrot yield is obtained with water application level of 151% Epan.

However, there is little information available in India regarding carrot irrigation management with high efficiency systems. Therefore, this study aimed at determining response of growth parameters by applying different irrigation and fertigation levels on a carrot crop under pulse drip irrigation was conducted in Konkan region of Maharashtra state.

Materials and methods

Experimental site

The field experiment was conducted at Instructional Farm of Department of Irrigation and Drainage Engineering, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The two *rabi* seasons trial of carrot were carried out, first research trial from 30th November 2019 to 2nd March 2020, while second research trial from 25th November 2020 to 26th February 2021. The experimental site is situated at 17^0 45' 13.1" N latitude and 73^0 10' 47.4" E longitudes and altitude of 250 m. Climatic conditions are humid with average annual rainfall at Dapoli region is 3635 mm (Mandale, 2016) [10].The average minimum and maximum temperatures are 18.5 °C to 31.0 °C, respectively. The relative humidity ranges from 55 percent to 99 percent (Gaikwad, 2013) [7].The soil type of experimental field was sandy clay loam textured and having pH-6.5, EC-0.45 $dS.m^{-1}$, bulk density-1.68 $g.cm^{-3}$, basic infiltration rate- 6.03 $cm.hr^{-1}$, field capacity-26.02% and permanent wilting point-12.50%.

Experimental design and crop

The experimental design was strip-split plot and replicated three times. The unit plot size was 22.0 m × 15.1 m having a single bed of 2 m × 0.80 m. Plant to plant and row to row spacing was 5 cm and 20 cm, respectively. The plots were fertilized with the recommended dose of water soluble fertilizer 100**:**60**:**80 $Kg.ha^{-1}$ N, P_2O_5 and K_2O fertilizers. The irrigation water of 63.9 and 67.2 millimeter had applied after sowing for the establishment of seedlings during 2019-20 and 2020-21, respectively. The inline lateral of 16 mm diameter with 4 Lph discharge having 40 cm spacing at 1.0 $Kg.cm^{-2}$ operating pressure was used. The daily water applied for carrot (*Daucus carota* L.) under pulse drip irrigation was worked out based on modified Penman-Monteith method (Allen *et al*. 1998) [4]. The necessary climatic data were collected from the weather station at Agronomy Department of the university, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The available discharge and emission uniformity of the drip system were recorded as 2.25 $L.h^{-1}$ and 95.26% for the year 2019-20 and 2.25 $L.h^{-1}$ and 94.50% for the year 2020-21, respectively. Water application in pulse treatments was imposed on 25th December 2019, in first-year trial and 20th December 2020 in second-year trial. Water application in pulse treatments was terminated on 27th February 2020, in first year trial and 23rd February 2021, in second year trial. The statistical analysis was done by "analysis of variance" appropriate for the 'strip-split plot design' with the statistical software SAS. The carrot cultivar used in the experiment was "Desi red" with daily values of K_c as 0.7, 1.05, 1.05 and 0.95 for the initial, crop development, mid and maturity stages of the carrot crop, respectively (Allen *et al*. 1998) [4]. The biometric observation of growth parameters were recorded from 30 DAS to 90 DAS on an interval of 15 days time. The plant growth parameters such as number of leaves per plant, plant height and plant canopy diameter of 5 randomly selected plants were recorded.

Results and discussion

Applied water volume

A. Gross depth of water applied

It was contemplated from Table 1, that total reference evapotranspiration during the crop growth period in year 2019-20 and 2020-21 was 325.3 mm and 296.1 mm, respectively. The crop evapotranspiration (net depth) during the year 2019-20 and 2020-21 was varied from 317.9 mm to 284.1 mm. From Table 1 total water applied under irrigation treatment I_1 (0.8 ETc) varied from 275.5 mm to 249.4 mm in the year 2019-20 and 2020-21, while it was ranged from 326.8 mm to 393.3 mm and 378.1 mm to 337.2 mm for irrigation treatments I_2 (1.0 ETc) and I_3 (1.2 ETc), respectively.

Table 1: Month wise and seasonal gross depth of water applied in different irrigation levels for carrot

Season	Irrigation level	Month					Total
		November (*)	December (*)	December (**)	January	February (#)	
2019-2020	ET_0	3.6	69.3	20.7	125.4	106.3	325.3
	ET_c	2.5	58.9	21.2	132.9	102.3	317.9
	$I_1(0.8ET_c$	2.6	61.3	17.7	109.4	84.6	275.5
	$I_2(1.0ET_c)$	2.6	61.3	21.9	136.0	105.0	326.8
	$I_3(1.2ET_c)$	2.6	61.3	26.2	162.6	125.5	378.1
2020-2021	ET_0	20.7	56.1	36.2	96.6	87.2	296.8
	ET_c	15.3	49.4	37.5	97.6	84.3	284.1
	I_1 $(0.8ET_c$	15.9	51.3	31.2	81.2	69.8	249.4
	$I_2(1.0ET_c)$	15.9	51.3	38.8	100.7	86.6	293.3
	$I_3(1.2ET_c)$	15.9	51.3	46.3	120.2	103.5	337.2
*	General irrigation for establishment of crop from 30 November to 24 December 2020 (I^{st} trial) and 25 November to 19 December 2020 (II^{nd} trial)						
**	Water application in pulse treatments were imposed from 25 December 2020 (I^{st} trial) and 20 December 2020 (II^{nd} trial)						
#	Water application in pulse treatments were terminated on 27 February 2020 (I^{st} trial) and 23 February 2021 (II^{nd} trial)						

B. Effect of different imposed variables on growth parameters of carrot

i. Effect of different pulses on growth parameters of carrot

The pooled effect of different pulses on growth parameters like number of leaves, plant height and plant canopy diameter of carrot cultivated during the year 2019-2020 and 2020-2021 are reported in Table 2 and represented in Fig. 1, Fig. 2 and Fig. 3 respectively.

Table 2: Effect of pulse irrigation on growth parameters of carrot

Pulse Number	Growth parameter at different days after sowing (DAS)														
	30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.
P_1	3.16	9.49	8.21	4.13	17.8	13.1	6.43	29	21.5	8.18	45.6	33.1	9.23	50.2	41.3
P_2	3	9.55	8.61	4.12	16.2	14.9	6.74	31.9	23.8	8.72	47.5	35.6	9.75	52.8	43.7
P_3	3.39	13.7	12.5	4.69	20.6	18	7.24	35.6	25.6	9.16	50.9	38.9	10.2	55.1	47
P_4	3.24	11.7	10.6	4.6	19.4	16.9	7.62	37.8	27.8	9.46	52.4	41.4	10.4	55.9	48.5
S.E.(m)±	0.06	0.40	0.29	0.05	0.47	0.25	0.02	0.14	0.16	0.02	0.16	0.22	0.05	0.12	0.25
C.D. at 5%	0.16	1.19	0.85	0.14	1.38	0.75	0.06	0.41	0.47	0.07	0.48	0.64	0.14	0.34	0.74

N.L. – Number of leaves, P.H. – Plant Height, P. C. – Plant Canopy diameter

The data reported in Table 2 shows that the growth parameters found to increase significantly from pulse P_1 to P_3 till 45 DAS and then found to be increased in specific trend i.e. P_1 to P_4 from 60 to 90 DAS. The maximum number of leaves 7.62, 9.46 and 10.4 was found in pulse number P_4 and superior to rest of pulses at 60, 75 and 90 DAS. The another growth parameter i.e. plant height also found maximum and superior in P_4 which was 37.8, 52.4 and 55.9 cm at 60, 75 and 90 DAS respectively. Further, maximum canopy diameter 27.8, 41.4 and 48.5 cm was obtained in P_4 pulse at 60, 75 and 90 DAS and superior to rest of all other pulses. It may be due to congenial moisture condition found in crop root zone in four pulse irrigation. The result of present study have similar trend with findings of Abuarab *et al.* (2011) [2] in case of green bean crop where highest value of growth parameter was found in P_4 pulse irrigation level.

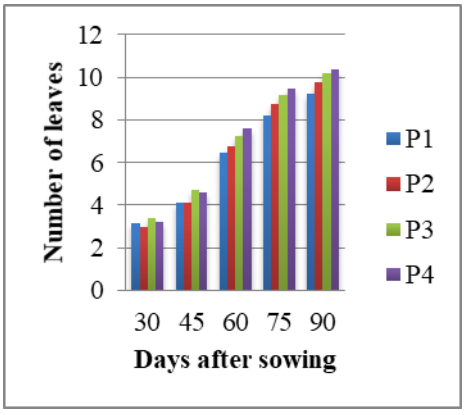

Fig 1: Effect of different pulses on number of leaves

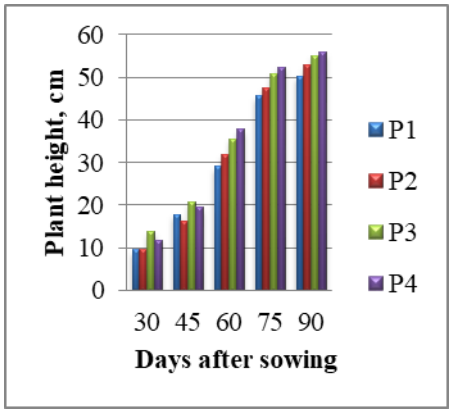

Fig 2: Effect of different pulses on plant height

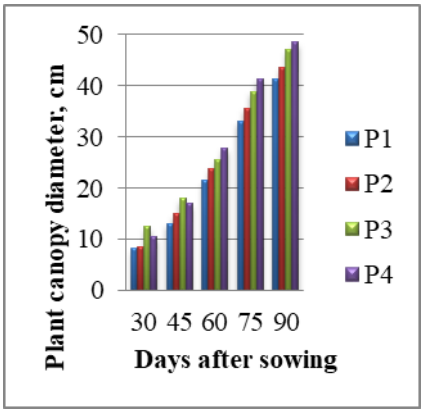

Fig 3: Effect of different pulses on canopy diameter

ii. Effect of irrigation levels on growth parameters of carrot

The pooled effect of different irrigation levels on growth parameters such as number of leaves, plant height and plant canopy diameter of carrot cultivated during the year 2019-2020 and 2020-2021 are reported in Table 3 and represented in Fig. 4, Fig. 5 and Fig. 6 respectively.

Table 3: Effect of different irrigation levels on growth parameters of carrot

Irrigation Level	Growth parameter at different days after sowing (DAS)														
	30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.
I_1	3.1	10.5	9.1	4.2	17.8	14.8	6.7	31.4	23	8.5	47	35.1	9.6	51.5	42.8
I_2	3.2	11.3	10.1	4.4	19.1	15.9	7.2	35.7	25.5	9.1	51.2	38.3	10	55	46.4
I_3	3.3	11.5	10.8	4.5	19.1	16.5	7.1	33.7	25.6	9.0	49.2	38.3	10	54	46.2
S.E.(m)±	0.05	0.35	0.25	0.04	0.41	0.22	0.02	0.12	0.14	0.02	0.14	0.19	0.04	0.1	0.22
C.D. at 5%	NS	NS	0.74	0.12	NS	0.65	0.06	0.35	0.41	0.06	0.42	0.56	0.12	0.3	0.64

It is observed from the data reported in Table 3 that the growth parameters found to increase from I_1 to I_3 till 45 DAS and then found to be increased from I_1 to I_2 and again decreased or equal in I_2 to I_3 during data recorded from 60 to 90 DAS except P.C. at 60 DAS. The maximum number of leaves 7.2, 9.1 and 10.0 was found in irrigation level I_2 at 60, 75 and 90 DAS which are found superior except at 90 DAS. The another growth parameter i.e. plant height also found maximum and superior in I_2 which was 35.7, 51.2 and 55.0 cm at 60, 75 and 90 DAS respectively. The maximum canopy diameter 25.6, 38.3 and 46.4 cm obtained in I_3, I_3 and I_2 irrigation levels at 60, 75 and 90 DAS. It may be due to favourable condition found in crop root zone which is responsible for particular growth parameter development in proper irrigation level. The results of present study on effect of different irrigation levels on growth parameters are as similar as with findings of Alam *et al.* (2010) [3] and Abdel-Mawly (2004) [1] in case of carrot crop where maximum value of growth parameter was found in irrigation level of 100% ETc of applied water.

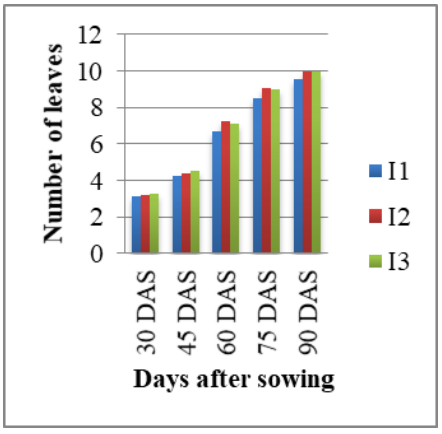

Fig 4: Effect of different irrigation levels on number of leaves

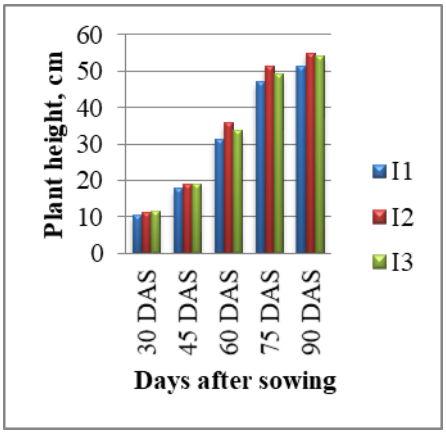

Fig 5: Effect of different irrigation levels on plant height

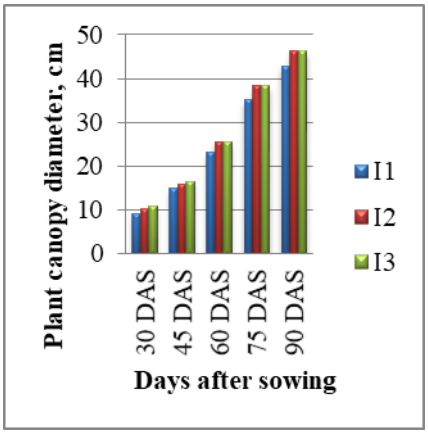

Fig 6: Effect of different irrigation levels on canopy diameter

iii. Effect of fertigation levels on growth parameters of carrot

The pooled effect of different fertigation levels on growth parameters as number of leaves, plant height and plant canopy diameter of carrot are reported in Table 4 and represented in Fig. 7, Fig. 8 and Fig. 9 respectively.

Table 4: Effect of different fertigation levels on growth parameters of carrot

Fertigation Levels	Growth parameter at different days after sowing (DAS)														
	30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.
F_1	3.14	10.6	9.26	4.25	17.9	14.8	6.77	31.8	23.5	8.68	47.7	35.7	9.68	52.1	43.4
F_2	3.16	10.7	9.98	4.42	18.5	15.9	7.04	34	24.9	8.92	49.5	37.7	9.91	54	45.7
F_3	3.29	12.0	10.7	4.48	19.2	16.5	7.2	35	25.6	9.05	50.1	38.3	10	54.4	46.3
S.E.(m)±	0.04	0.41	0.19	0.04	0.53	0.33	0.02	0.1	0.17	0.02	0.2	0.14	0.03	0.07	0.2
C.D. at 5%	NS	NS	0.76	0.17	NS	NS	0.06	0.41	0.68	0.08	0.78	0.55	0.13	0.29	0.79

It is reported in Table 4 that the growth parameters found to increase from F_1 to F_3 from 30 to 90 DAS however effect of significance observed from 60 to 90 DAS. The maximum number of leaves 3.29, 4.48, 7.20, 9.05 and 10.0 was found in fertigation level F_3 at 30, 45, 60, 75 and 90 DAS. The second growth parameter i.e. plant height also found maximum in F_3 which was 12.0, 19.2, 35.0, 50.1 and 54.4 cm at 30, 45, 60, 75 and 90 DAS respectively. Further, maximum canopy diameter 10.7, 16.5, 25.6, 38.3 and 46.3 cm was obtained in F_3 fertigation levels at 30, 45, 60, 75 and 90 DAS AS. It may be due to more nutrient availability in F_3 fertigation level which results pleasant growth of crop.

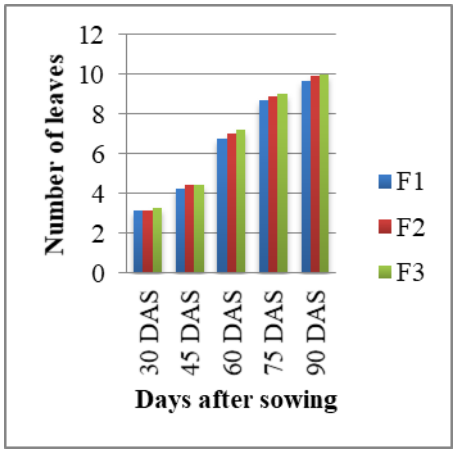

Fig 7: Effect of different fertigation levels on number of leaves

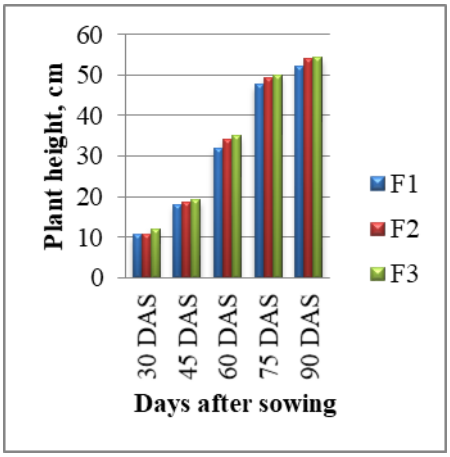

Fig 8: Effect of different fertigation levels on plant height

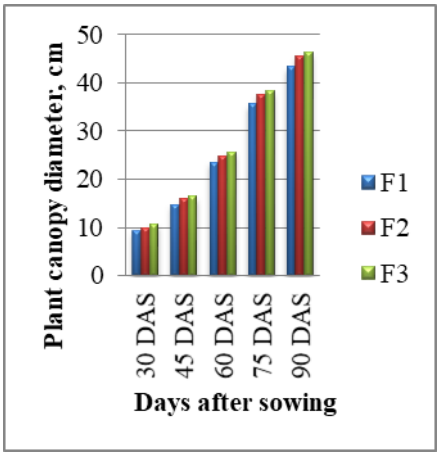

Fig 9: Effect of different fertigation levels on canopy diameter

The results of current study on effect of different fertigation levels on growth parameters are as related as with findings of Abdel-Mawly (2004) [1], Murthy *et al.* (2016) [11] and Kharsan *et al.* (2019) [9] in case of carrot crop where plant growth parameters was found to be increased on increasing level of nutrients from 0 kg/fed to 120 kg/fed.

iv. Interaction effect of pulse and irrigation levels on growth parameters of carrot

The pooled effect of interaction of pulse and irrigation levels on growth parameters like number of leaves, plant height and plant canopy diameter of carrot cultivated during the year 2019-2020 and 2020-2021 are reported in Table 5 and represented in Fig. 10, Fig. 11 and Fig. 12 respectively.

Table 5: Effect of pulse and irrigation levels on growth parameters of carrot

Treatment combination	Growth parameter at different days after sowing (DAS)														
	30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.
P_1I_1	3.1	8.56	7.07	4	16.6	12.5	6.07	26.8	19.8	7.64	44.3	31.2	8.67	47.6	39.1
P_1I_2	3.16	9.14	8.34	4.16	17.8	12.9	6.59	29.6	22.2	8.46	46	33.9	9.44	50.9	42.5
P_1I_3	3.23	10.8	9.23	4.22	18.9	14	6.62	30.7	22.5	8.43	46.4	34.1	9.58	52.2	42.3
P_2I_1	2.89	8.81	7.66	3.96	16.1	13.8	6.54	29.8	22.6	8.55	45	33.9	9.51	50.5	42.1
P_2I_2	2.97	9.73	8.49	4.04	16	15.2	6.92	34.2	24.4	8.85	49.6	36.7	9.98	54.9	44.8
P_2I_3	3.13	10.1	9.68	4.36	16.6	15.9	6.75	31.9	24.3	8.76	47.8	36.2	9.75	53	44.1
P_3I_1	3.32	12.4	11.3	4.57	20.1	16.8	6.96	33.2	24.4	8.92	48.7	36.9	10	53.7	45.1
P_3I_2	3.41	14.4	12.9	4.77	21.5	18.3	7.39	38.6	26.6	9.32	53.6	40.3	10.3	56.8	48.4
P_3I_3	3.42	13.2	13.3	4.73	20.2	18.9	7.36	34.8	25.7	9.25	50.5	39.4	10.2	54.9	47.5
P_4I_1	3.24	12.3	10.2	4.4	19.1	16.2	7.08	35.8	25.2	9.04	49.9	38.3	10.1	54.2	44.8
P_4I_2	3.27	12.4	10.6	4.69	21.1	17.1	7.98	40.6	28.7	9.74	55.6	42.2	10.5	57.6	49.7
P_4I_3	3.22	12	11.1	4.7	20.7	17.3	7.81	37.2	29.6	9.59	51.9	43.6	10.4	55.8	51.0
S.E.(m)±	0.1	0.7	0.5	0.08	0.82	0.44	0.04	0.24	0.28	0.04	0.29	0.38	0.08	0.2	0.43
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.11	0.71	0.81	0.13	0.84	1.12	0.25	0.6	1.27

It is revealed from Table 5 that interaction effect of pulse and irrigation levels on growth parameters are found non-significant till 45 DAS and then found significant from 60 to 90 DAS. The maximum number of leaves 7.98, 9.74 and 10.5 was found in P_4I_2 which is superior to rest treatments at 60, 75 and 90 DAS except at 90 DAS. It further reported that highest and superior value of plant height also obtained from P_4I_2 treatment combination those were 40.6, 55.6 and 57.6 cm at 60, 75 and 90 DAS respectively. The maximum value of canopy diameter i.e. 29.6, 43.6 and 51.0 cm was obtained from P_4I_3 treatment combination which is superior to rest of treatments at 60, 75 and 90 DAS. The minimum value of growth parameters as tabulated in Table 5 was found in treatment combination P_1I_1.

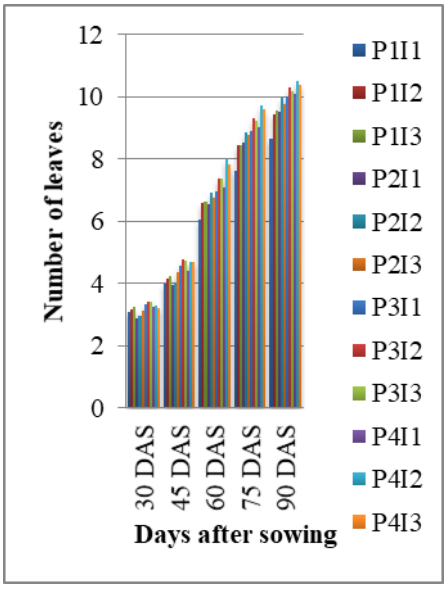

Fig 10: Interaction effect of pulse and irrigation levels on number of leaves

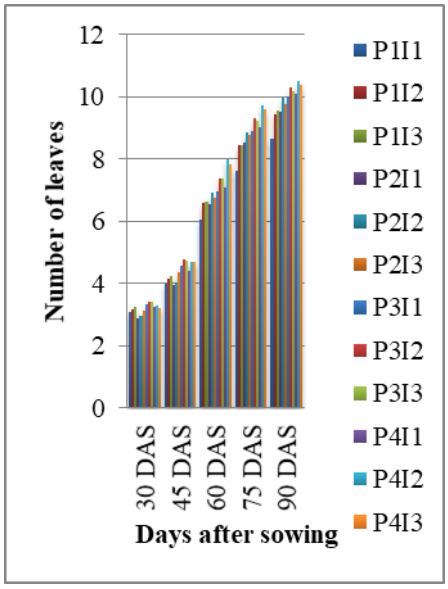

Fig 11: Interaction effect of pulse and irrigation levels on plant height

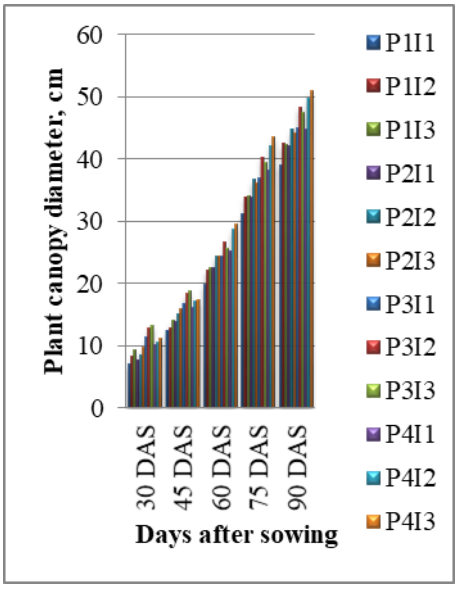

Fig 12: Interaction effect of pulse and irrigation levels on canopy diameter

The interaction effect of pulse irrigation and irrigation levels on growth parameters have as similar as results to the scientists El-Saidi *et al.* (2010) [6] in case of potato crop where plant growth was increased by increasing number of irrigation pulses from P_1 (one time) to P_4 (four time) and at irrigation level from 100% ETc of total applied water. They found maximum leaf area from combined levels of pulse irrigation (P_4) and irrigation level (I_3) i.e. P_4I_3.

v. Interaction effect of pulse and fertigation levels on growth parameters of carrot

The pooled effect of interaction of pulse and fertigation levels on growth parameters for example number of leaves, plant height and plant canopy diameter of carrot cultivated during the year 2019-2020 and 2020-2021 are reported in Table 6 and represented in Fig. 13, Fig. 14 and Fig. 15 respectively.

Table 6: Effect of pulse and fertigation levels on growth parameters of carrot

Treatment combination	Growth parameter at different days after sowing (DAS)														
	30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.
P_1F_1	3.08	8.99	7.2	4	17.1	12.1	6.14	26	19.8	7.81	42.9	30.6	8.85	46.6	39.1
P_1F_2	3.16	8.44	8.0	4.14	17.1	13.2	6.41	29.7	21.9	8.21	45.8	33.3	9.26	51	41.3
P_1F_3	3.26	11	9.5	4.23	19.1	14.1	6.72	31.5	22.9	8.51	48	35.2	9.59	53	43.6
P_2F_1	2.99	9.1	8.2	3.99	15.4	13.7	6.5	29.9	22.6	8.53	45.2	33.6	9.48	50.9	41.7
P_2F_2	2.93	8.9	8.3	4.13	16.2	15.2	6.78	32.3	24.0	8.74	47.9	36.2	9.83	53.6	44.4
P_2F_3	3.07	10.6	9.4	4.24	17	15.9	6.93	33.6	24.7	8.89	49.3	37.1	9.93	53.9	45.0
P_3F_1	3.3	13.1	11.5	4.48	20.3	17.1	7.05	34.3	24.6	8.99	50.7	37.9	10.1	54.9	45.5
P_3F_2	3.32	13.9	12.9	4.77	21.1	18.1	7.31	35.9	25.7	9.23	51.6	39.4	10.2	55.6	47.9
P_3F_3	3.53	14.2	13.1	4.82	20.4	18.8	7.35	36.5	26.3	9.28	50.5	39.2	10.2	54.9	47.6
P_4F_1	3.2	11.3	10.2	4.51	18.8	16.4	7.38	37.3	26.8	9.38	52	40.7	10.3	55.8	47.5
P_4F_2	3.21	11.5	10.8	4.63	19.5	17.1	7.68	38	28.1	9.49	52.7	41.9	10.3	55.9	49.2
P_4F_3	3.32	12.4	10.9	4.64	20	17.2	7.81	38.3	28.6	9.51	52.6	41.6	10.4	55.8	48.8
S.E(m)±	0.06	0.47	0.31	0.07	0.66	0.32	0.02	0.27	0.22	0.04	0.28	0.41	0.06	0.27	0.24
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.07	0.76	NS	0.13	0.79	1.16	0.16	0.76	0.68

The data from Table 6 revealed that interaction effect of pulse and fertigation levels on growth parameters are found significant from 60 to 90 DAS except plant canopy diameter at 60 DAS. The maximum number of leaves 7.81, 9.51 and 10.4 was found in P_4F_3 which is at par to P_4F_2 at 60, 75 and 90 DAS except at 60 DAS. It further reported that highest plant height 38.3 cm in P_4F_3, 52.7 and 55.9 cm in P_4F_2 was obtained at 60, 75 and 90 DAS respectively. The maximum value of canopy diameter reported from table was 28.6 cm in P_4F_3, 41.9 and 49.2 cm in P_4F_2 at 60, 75 and 90 DAS however both treatments P_4F_2 and P_4F_3 are found at par to each other. The minimum value of growth parameters as tabulated in Table 6 was found in treatment combination P_1I_1. The result clearly indicated that maximum number of pulses and nutrient created favorable condition for plant growth and development.

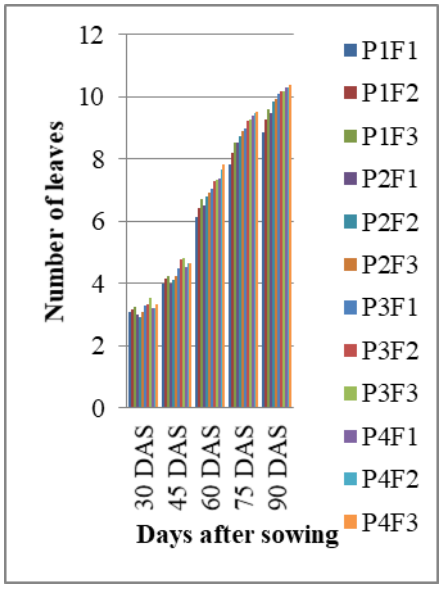

Fig 13: Interaction of pulse and fertigation levels on number of leaves

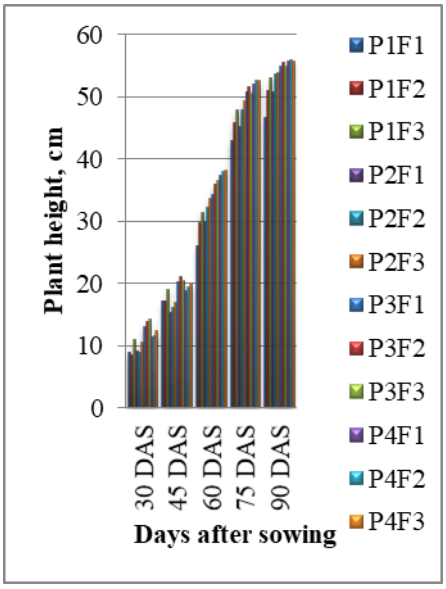

Fig 14: Interaction of pulse and fertigation levels on plant height

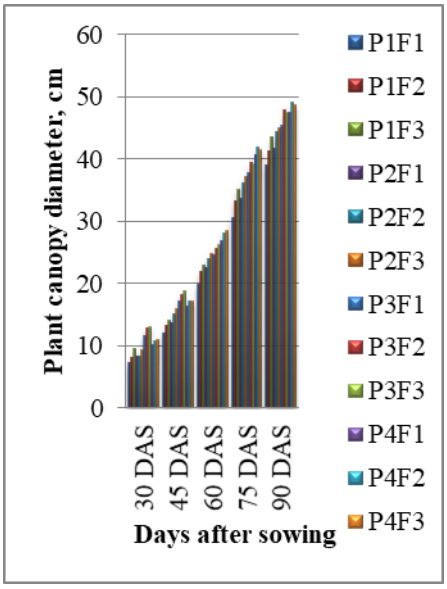

Fig 15: Interaction of pulse and fertigation levels on canopy diameter

vi. Interaction effect of fertigation and irrigation levels on growth parameters of carrot

The pooled effect of interaction of fertigation and irrigation levels on growth parameters as number of leaves, plant height and plant canopy diameter of carrot cultivated during the year 2019-2020 and 2020-2021 are reported in Table 7 and represented in Fig. 16, Fig. 17 and Fig. 18 respectively.

Table 7: Effect of irrigation and fertigation levels on growth parameters of carrot

Treatment combination	Growth parameter at different days after sowing (DAS)														
	30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.
F_1I_1	3.02	10.1	8.2	4.05	16.8	13.6	6.76	31.5	23.1	8.69	47.3	35.5	9.7	50.7	43.3
F_2I_1	3.09	10.1	9.3	4.33	17.8	15.2	6.7	32.3	23.2	8.51	47.7	35.6	9.61	52.6	43.2
F_3I_1	3.31	11.4	9.7	4.31	18.8	15.7	6.52	30.4	22.6	8.42	45.9	34.1	9.43	51.2	41.8
F_1I_2	3.18	10.7	9.3	4.27	17.8	15.2	6.86	33	23.9	8.76	48.7	36.2	9.71	52.9	44.0
F_2I_2	3.18	10.7	9.9	4.4	18.8	15.8	7.26	36.3	25.8	9.14	51.9	38.8	10.1	55.8	47.0
F_3I_2	3.24	12.6	11.1	4.58	19.3	16.7	7.53	37.9	26.8	9.38	52.9	39.8	10.4	56.3	48.2
F_1I_3	3.23	11.1	10.4	4.42	19	15.7	6.69	31	23.3	8.58	47.1	35.3	9.62	52.5	43.0
F_2I_3	3.2	11.2	10.8	4.53	18.9	16.7	7.16	33.3	25.8	9.1	48.9	38.7	10	53.7	46.9
F_3I_3	3.33	12.2	11.4	4.57	19.4	17.2	7.55	36.6	27.5	9.34	51.5	40.9	10.3	55.6	48.8
S.E(m)±	0.05	0.4	0.27	0.06	0.57	0.27	0.02	0.23	0.19	0.04	0.24	0.35	0.05	0.23	0.21
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.06	0.65	0.55	0.11	0.69	1	0.14	0.66	0.59

The data reported from Table 7 revealed that interaction effect of fertigation and irrigation levels on growth parameters are found significant from 60 to 90 DAS. The maximum number of leaves 7.55 in F_3I_3, 9.38 and 10.4 in F_3I_2 was found at 60, 75 and 90 DAS with both treatments F_3I_2 and F_3I_3 are found at par to each other. It further reported that highest plant height 37.9, 52.9 and 56.3 cm was obtained from treatment combination F_3I_2 at 60, 75 and 90 DAS respectively. From Table 7, the treatment combination F_3I_3 revealed maximum and superior value of canopy diameter which was reported as 27.5, 40.9 and 48.8 cm at 60, 75 and 90 DAS. The minimum value of growth parameters as tabulated in Table 7 was found in treatment combination F_3I_1. It might be toxic effect of high nutrient value at limited quantity of water.

The result of interaction effect of irrigation and fertigation levels on carrot is related to findings of Venkatesan *et al.* (2014) [20] in case of elephant foot yam crop where growth parameters was found maximum at highest level of fertigation and higher level of irrigation water. It is observed from present study result that maximum growth parameters obtained from treatment combination 'F_3I_2' and 'F_3I_3'which is highest level of fertigation and higher level of irrigation.

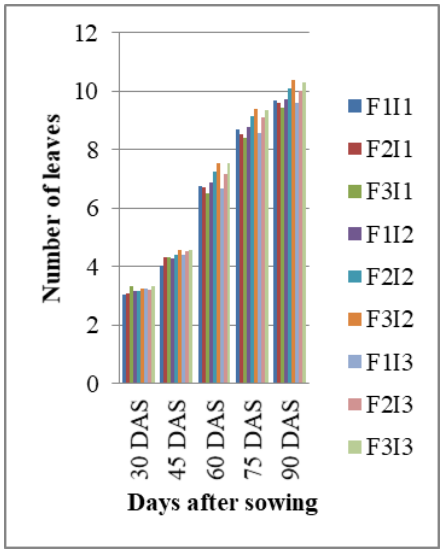

Fig 16: Interaction effect of fertigation and irrigation levels on number of leaves

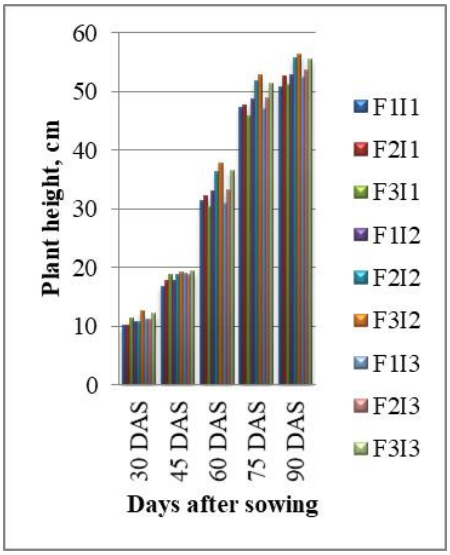

Fig 17: Interaction effect of fertigation and irrigation levels on plant height

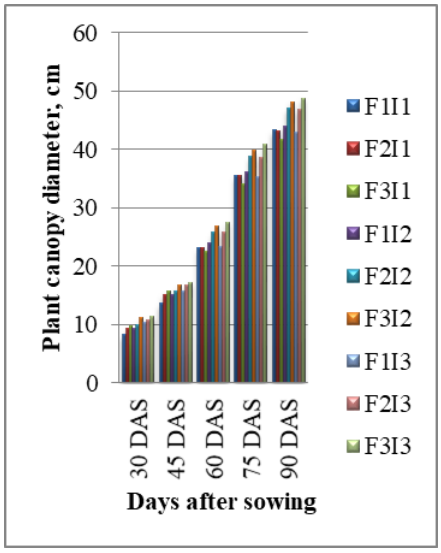

Fig 18: Interaction effect of fertigation and irrigation levels on canopy diameter

vii. Interaction effect of pulse, irrigation and fertigation levels on growth parameters of carrot

The pooled effect of interaction of pulse, irrigation and fertigation levels on growth parameters for instance number of leaves, plant height and plant canopy diameter of carrot cultivated during the year 2019-2020 and 2020-2021 are reported in Table 8 and represented in Fig. 19, Fig. 20 and Fig. 21 respectively.

The data reported in Table 8 revealed that interaction effect of pulse, irrigation and fertigation levels on growth parameters are found significant from 60 to 90 DAS except number of eaves at 90 DAS. The maximum number of leaves i.e. 8.38, 9.91 and 10.8 was found in treatment combinations $P_4I_3F_3$ at 60, 75 and 90 DAS. Further, it is reported that highest plant height 42.5, 57.0 and 58.6 cm was obtained from treatment combination $P_4I_2F_3$ at 60, 75 and 90 DAS respectively which is at par to $P_4I_2F_2$. The treatment combination $P_4I_3F_3$ responded maximum and superior (except 75 DAS) value of canopy diameter which was reported as 32.8, 46.2 and 53.9 cm at 60, 75 and 90 DAS. The minimum value of growth parameters as tabulated in Table 8 was found in treatment combination $P_1I_1F_1$. It is clearly indicated that maximum pulses i.e. P_4 with maximum irrigation and fertigation level i.e. I_2 or I_3 and F_3 creates the conditions for pleasant crop growth which ultimately results in achieving luxurious development in growth parameters.

Table 8: Interaction effect of pulse, irrigation and fertigation levels on growth parameters of carrot

Treatment combination	Growth parameter at different days after sowing (DAS)														
	30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.	N. L.	P. H.	P. C.
$P_1I_1F_1$	2.9	8.57	5.55	3.67	15.6	11.5	5.9	23.7	18.7	7.46	41.7	29.2	8.45	44.5	37.2
$P_1I_1F_2$	3.13	7.43	7	4.13	15.5	12.7	6.12	27.7	20	7.58	44.7	31.8	8.63	48	39.3
$P_1I_1F_3$	3.27	9.67	8.67	4.2	18.7	13.3	6.19	28.9	20.8	7.88	46.5	32.5	8.94	50.3	40.7
$P_1I_2F_1$	3.2	8.27	7.63	4.17	16.4	11.9	6.32	25.6	20.4	8.1	42.6	31.3	9.03	45.3	40.5
$P_1I_2F_2$	3.13	8.23	7.88	4.17	18	12.4	6.48	30.8	22.4	8.43	46.9	34	9.44	53.5	41.8
$P_1I_2F_3$	3.13	10.9	9.5	4.13	19.1	14.4	6.98	32.5	24	8.84	48.5	36.4	9.84	53.8	45.3
$P_1I_3F_1$	3.13	10.1	8.3	4.17	19.2	12.9	6.22	28.7	20.3	7.87	44.5	31.2	9.06	50.1	39.4
$P_1I_3F_2$	3.2	9.67	9.1	4.13	17.9	14.4	6.63	30.5	23.3	8.6	45.8	34.2	9.7	51.5	42.8
$P_1I_3F_3$	3.37	12.5	10.3	4.37	19.6	14.8	7	32.9	24.1	8.82	49.1	36.8	9.98	55	44.7
$P_2I_1F_1$	2.9	8.3	7.39	3.8	15.3	11.8	6.63	27.8	21.8	8.65	42.8	33.3	9.53	47.1	41.6
$P_2I_1F_2$	2.73	7.77	7.03	4	16.2	14.4	6.54	31.8	23.5	8.58	47.4	34.9	9.65	53.6	43.2
$P_2I_1F_3$	3.03	10.4	8.57	4.07	16.7	15.1	6.45	29.6	22.4	8.42	44.9	33.5	9.33	50.8	41.6
$P_2I_2F_1$	2.93	9.2	7.68	3.9	15.4	14.2	6.53	32	23.2	8.53	47.1	34.4	9.55	54.1	42.3
$P_2I_2F_2$	2.97	8.87	7.47	4.03	15.6	15.1	7.06	34	24.6	8.92	49.7	37.5	10.1	55	45.9
$P_2I_2F_3$	3	11.1	10.3	4.2	17.1	16.1	7.16	36.5	25.6	9.1	52	38.3	10.3	55.5	46.4
$P_2I_3F_1$	3.13	9.8	9.4	4.27	15.6	15.1	6.34	29.8	23	8.4	45.6	33	9.35	51.4	41.2
$P_2I_3F_2$	3.1	10.1	10.3	4.35	16.9	16	6.73	31.1	23.9	8.72	46.8	36.1	9.77	52.3	44.1
$P_2I_3F_3$	3.17	10.4	9.35	4.45	17.3	16.6	7.18	34.6	26.1	9.15	50.9	39.6	10.1	55.3	47
$P_3I_1F_1$	3.13	11.2	9.82	4.43	18.3	15.3	7.22	35.3	25.5	9.27	51.7	39.3	10.4	55.3	47.5
$P_3I_1F_2$	3.3	12.9	12.4	4.63	21.2	17.1	7.03	33.6	24.3	8.88	49.1	37	10	54.1	45.5
$P_3I_1F_3$	3.53	13.2	11.7	4.63	20.9	18	6.62	30.8	23.4	8.62	45.4	34.5	9.59	51.7	42.2
$P_3I_2F_1$	3.37	15.1	11.6	4.48	22.6	18	6.85	36.5	24.3	8.79	51.9	37.5	9.9	55.9	44.5
$P_3I_2F_2$	3.33	14.6	12.9	4.8	21.2	18.1	7.53	39.3	26.9	9.45	54.8	41.3	10.3	57.1	49.6
$P_3I_2F_3$	3.53	16.8	14.1	5.51	20.8	18.9	7.78	40	28.6	9.72	54.1	42.1	10.6	57.4	51.2
$P_3I_3F_1$	3.4	12.9	13.1	4.53	20	18.1	7.08	31	24.1	8.91	48.4	36.9	9.92	53.7	44.5

$P_3I_3F_2$	3.33	14.2	13.2	4.88	21.1	19	7.35	34.9	26.1	9.35	51	40.1	10.3	55.5	48.6
$P_3I_3F_3$	3.53	12.5	13.6	4.78	19.5	19.6	7.65	38.6	27	9.5	52.2	41.2	10.5	55.6	49.5
$P_4I_1F_1$	3.13	12.2	9.92	4.3	18.2	15.9	7.3	39.2	26.6	9.37	53	40.2	10.5	56	47
$P_4I_1F_2$	3.2	12.4	10.7	4.57	18.4	16.5	7.13	36	25.2	9	49.8	38.6	10.1	54.5	44.7
$P_4I_1F_3$	3.4	12.2	10	4.33	18.8	16.3	6.82	32.2	23.9	8.75	47	35.9	9.86	52.1	42.6
$P_4I_2F_1$	3.23	10.3	10.1	4.53	16.9	16.6	7.73	38.1	27.8	9.6	53.2	41.6	10.4	56.5	48.6
$P_4I_2F_2$	3.27	11.2	11.3	4.6	20.3	17.5	7.98	41.2	29.3	9.77	56.3	42.6	10.5	58.0	50.6
$P_4I_2F_3$	3.3	11.4	10.4	5.25	20.1	17.3	8.22	42.5	29	9.87	57	42.5	10.7	58.6	50.1
$P_4I_3F_1$	3.23	11.5	10.7	4.7	21.3	16.7	7.12	34.5	26.1	9.16	49.8	40.2	10.2	55	46.9
$P_4I_3F_2$	3.17	10.9	10.4	4.73	19.7	17.3	7.92	36.7	30	9.72	51.9	44.4	10.4	55.6	52.3
$P_4I_3F_3$	3.27	13.5	12.4	4.67	21.2	17.8	8.38	40.4	32.8	9.91	53.9	46.2	10.8	56.7	53.9
S.E(m)±	0.11	0.81	0.54	0.12	1.14	0.55	0.04	0.46	0.39	0.08	0.48	0.7	0.1	0.46	0.41
C.D. at 5%	NS	NS	1.54	NS	NS	NS	0.12	1.31	1.1	0.22	1.38	2.01	NS	1.32	1.17

The pioneer research work on interaction effect of different pulse, irrigation and fertigation levels on growth parameters of carrot has some similarities with findings of the scientists Abuarab *et al.* (2011) [2] and Venkatesan *et al.* (2014) [20]. Abuarab *et al.* (2011) [2] found for green bean crop that growth parameters was increased by increasing number of irrigation pulses from P_1 (one time) to P_4 (four time). Whereas, the result of Venkatesan *et al.* (2014) [20] revealed that growth parameters was found maximum at highest level of fertigation and higher level of irrigation water. The result obtained from present study providing maximum growth parameters from treatment combination as number of leaves per plant in $P_4I_3F_3$, plant height in $P_4I_2F_3$ and plant canopy diameter in $P_4I_3F_3$.

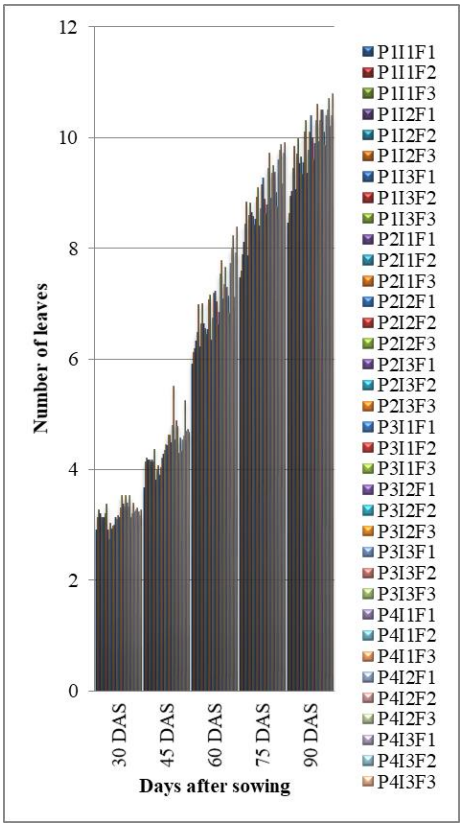

Fig 19: Interaction effect of pulse, irrigation and fertigation levels on number of leaves

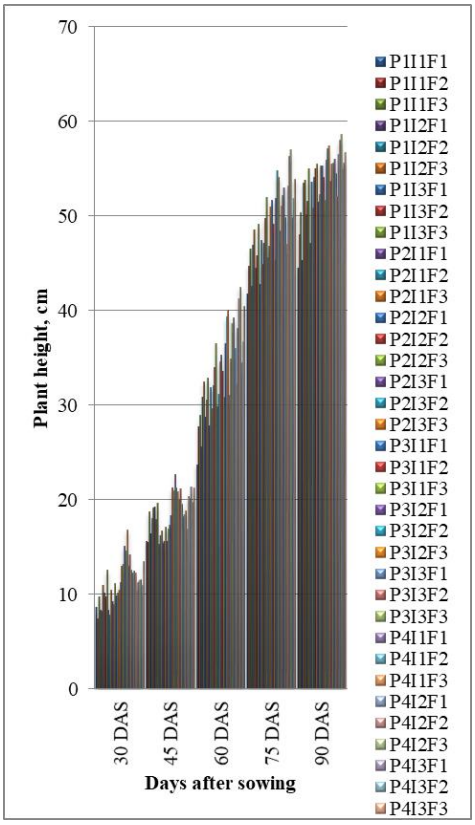

Fig 20: Interaction effect of pulse, irrigation and fertigation levels on plant height

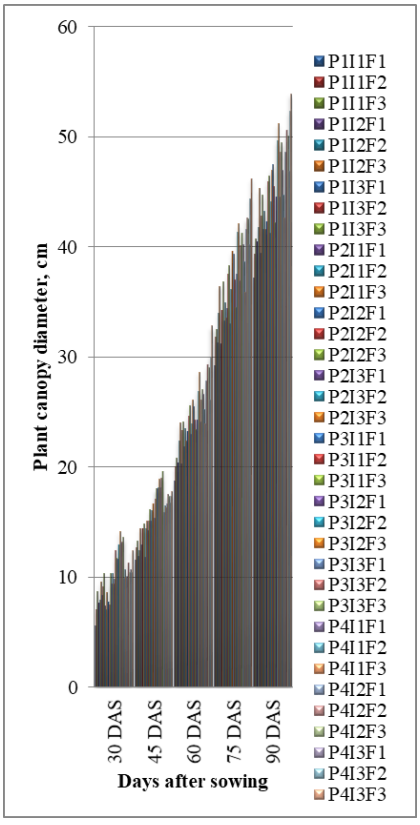

Fig 21: Interaction effect of pulse, irrigation and fertigation levels on canopy diameter

Conclusion

In present study input resources was water and fertilizer quantity along with recent technology pulse irrigation, which concluded as:

1. The plant growth parameters like number of leaves and canopy diameter has shown highest value in $P_4I_3F_3$, where available soil moisture depletion was observed less than 20% before irrigation and slightly higher than field capacity after 2 hrs of irrigation about the emitter at 30 cm depth with more nutrient availability, which might have creates favorable environment in root zone for vegetative growth.
2. The plant height has shown highest value in $P_4I_2F_3$, where soil moisture observed near to field capacity after 2 hrs of irrigation about the emitter at 30 cm depth, and at same time the nutrient availability was more, which might have created good environment for plant height growth.
3. The result concluded from present study that four pulses with slightly more or equal water and nutrient than crop water requirement and recommended dose of fertilizer achieve luxurious growth of carrot in agro-climatic region of Konkan area of Maharashtra.

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