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Productivity of Garden Pea (*Pisum sativum* L.) Under Abiotic Stress and Modified Bio-climatic condition

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A B S T R A C T

A field experiment was conducted during rabi (winter) season, 2017-18 and 2018-19 to study the effect of abiotic stress and modified bio climatic condition on productivity of garden pea. Pea varieties V_1 (Azad pea 3), V_2 (PSM 3) were sown under three row spacing viz. S_1=40×15 cm, S_2=35×10 cm, S_3= 30×5 cm and two irrigation levels I_1 (irrigation at flowering and pod filling stages) and I_2 (irrigation at 10 days intervals). Total Green seed yield was 6.34 t/ha for S_1 spacing where S_3 provided only 5.28 t/ha. Number of pods per plant was maximum in case of I_2 than I_1 and green seed yield were higher in case of I_2 (6.06 t/ha) than I_1 (5.44 t/ha). Relationships were developed between Stress degree days (SDD) and green seed yield indicated that SDD influenced seed yield throughout the growing period, R^2=0.678 at 60 DAS, R^2=0.594 at 75 DAS.

Introduction

Pea (*Pisum sativum* L.) is an important legume crop, grown as a garden and field crop, Botanically, pea belongs to the genus Pisum and species sativum, which is further divided into two cultivated varieties hortense and arvense. The Garden Pea (*P. sativum* L.) (2n=2x=14) comes under the variety hortense (Ambrose, 1995). It is a popular as well as economically important vegetable because of its high proteins, vitamins and minerals content. In India, it is cultivated in an area of 4.20 lakh ha with a production of 40.06 lakh MT and a productivity is 9.50 MT/ha but in West Bengal, it is cultivated in an area of 0.22 lakh ha with a production of 1.3 lakh MT but productivity of the crop is low (6.1 MT/ha) as compared to national productivity (Anonymous, 2014). Pea cultivation is widespread in areas having a mild and warm climate, because relatively high or low temperatures are the most important factors limiting pea cultivation (Ambrose, 2008). However, adequate data to measure the effect of plant species, spacing, irrigation and various climatic effects on the yield of garden pea are limited. So, the studies in this direction for improving yield of garden pea are very essential. Therefore, the aim of study is to investigate the effect of different species, spacing, irrigation, and various meteorological parameters (canopy temperature, soil temperature) on the production component of garden pea. In view of this fact the objective of this study is to investigate the effect of abiotic stress on productivity of garden pea and to estimate the production component of garden pea under different modified micro climate.

Materials and Methods

The field experiment was conducted during rabi (winter) season, 2017-18 and 2018-19 at the Instructional Farm, Jaguli, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal (Latitude: 22˚56' N, Longitude: 88º32' E and Altitude: 9.75 m above mean sea level). The meteorological pooled data of two years (2017-18 & 2018-19) were recorded during experimental period. The average mean weekly maximum temperature ranges of two year from 20.61^{o}C to 28.5^{o}C with an average of 25.64^{o}C. The average mean weekly minimum temperature ranges from 8.04^{o}C to 14.48^{o}C with an average 9.38^{o}C during the crop growth period. The average mean weekly rainfall ranges from minimum 0.4 mm to 3.42 mm with an average 0.29 mm. The experiment was laid out in a Randomized Block Design with two replications. Two varieties like Azad pea 3 and PSM-3 were cultivated, three spacing level of 40×15 cm (S_1), 35×10 cm (S_2) and 30×5 cm (S_3), two irrigation level for applied during 10 days interval (I_1) and other applied only at critical stages (I_2). Each Plot size was 3 × 2 m. Seed rate was 80 kg/ha, Fertiliser dose was N: P_2O_5:K_2O=25:50:50 where N = 25 kg/ha (32.604 gm. urea /plot) Phosphorus (P) = 50 kg/ ha (188 gm. SSP/ plot), Potassium (K) = 50 kg/ha (50 gm. MOP/plot) in each year. Total plant samples were collected from each plot (1 square meter area) to estimate dry matter accumulation at 15 days intervals. Total number of pods picked up from the tagged plants were counted under each plot and divided with the number of tagged plants to get average number of pod per plant. After harvesting the individual green seeds from each green pod (1 square meter area) were collected and weight was done and expressed in t ha^{-1}.The canopy temperature was measured with the help of infrared thermometer (IRT) at 15 days interval. The soil temperature was measured with the help of soil thermometer at 15 days intervals from each plot one from 5 cm depth and another from 15 cm depth. Stress Degree Days was calculated from the difference between canopy temperature and air temperature (CT-AT).

Results and Discussion

Dry matter production

Figure 1 shows that dry matter production in plant in different stages have a clear and significant effect due to different variety. Azad pea3 (V_1) produced more dry matter than PSM 3(V_2). Higher plant growth in terms of plant height and number of leaves might have enhanced photosynthesis resulted in more accumulation of food material which was reflected as higher dry weight per plant during different time interval. It is also noted that different levels of spacing have pronounced effect on plant dry matter production throughout the growth period. In case of S_1 (40×15 cm) plant produce more dry matter than other two spacing S_2 (35×10 cm) and S_3 (30×5 cm) at every stages of growth. Dry matter yield of pea as a whole increased significantly with the increase in plant spacing at 30th day and harvest during both the years. Wide row spacing helped in enhanced supply of various inputs like water, nutrient and light (K. B. Singh *et al.*,)˙ In this experiment two different irrigation levels shows significant effect on total dry matter accumulation of field pea. It is noted that in case of I_2 plant produce more dry matter than

I_1. Plants receiving I_2 accumulated more dry matter than I_1 (due to lesser abiotic stress under I_2 than I_1). High water treatment produces more dry matter of vines and pea than the medium and latter (Maurer *et al*.,).

Soil temperature (^oC) at 5 cm depths as influenced by different varieties, spacing & irrigation on of Garden pea

Soil temperature at 5 cm depth was greatly influenced by different level of spacing whereas there was no significant change due to the presence of cultivar. Effect of spacing have significant effect on soil temperature. Figure 2 shows that maximum significant effect of soil temperature (CD at 5% 1.25) by spacing 45×15 cm (S_1) at 45 DAS and minimum (0.65) was at 60 DAS by 35×10 cm (S_2) spacing. It also noted that with increasing plant density soil temperature was in decreasing trend, as minimum surface is exposed to solar radiation. This result is supported by Gupta *et al.*, (1981) that surface temperature and solar radiation regulate the soil temperature in soil field. In this experiment two different irrigation levels give significant effect on soil temperature at 5 cm depth at 30, 45, 60, and 75 DAS. Figure 3 shows that more soil temperature in case of I_2 (irrigation at 10 days interval) than I_1 (irrigation at critical stages). Critical difference is maximum (1.02) in case of I_2 at 45 DAS and minimum (0.53) at 60 DAS.

Table.1 Measurement of crop canopy temperature (°C) as influenced by different varieties, spacing & irrigation of Garden pea (pooled data of 2017-18 & 2018-19)

Treatments		30 DAS	45 DAS	60 DAS	75 DAS
V1(Azad Pea 3)		16.09	15.28	16.23	16.38
V2(PSM-3)		16.42	15.87	16.80	16.92
SEm(±)		0.07	0.11	0.04	0.04
CD at 5%		0.20	0.31	0.12	0.13
S1(40×15)		15.76	14.84	15.60	15.98
S2(35×10)		16.22	15.41	16.34	16.64
S3(30×5)		16.79	16.48	17.60	17.33
SEm(±)		0.08	0.13	0.05	0.05
CD at 5%		0.24	0.38	0.14	0.15
I1(Only at critical stages)		17.67	16.38	17.49	17.63
I2(at 10 days interval)		14.84	14.77	15.54	15.67
SEm(±)		0.07	0.11	0.04	0.04
CD at 5%		0.20	0.31	0.12	0.13
V×S	SEm(±)	0.12	0.18	0.07	0.07
	CD at 5%	0.34	NS	0.20	0.22
V×I	SEm(±)	0.10	0.15	0.06	0.06
	CD at 5%	NS	0.44	0.16	0.18
S×I	SEm(±)	0.12	0.18	0.07	0.07
	CD at 5%	0.34	0.53	0.20	0.22
V×S×I	SEm(±)	0.17	0.26	0.10	0.10
	CD at 5%	0.49	NS	0.28	0.31

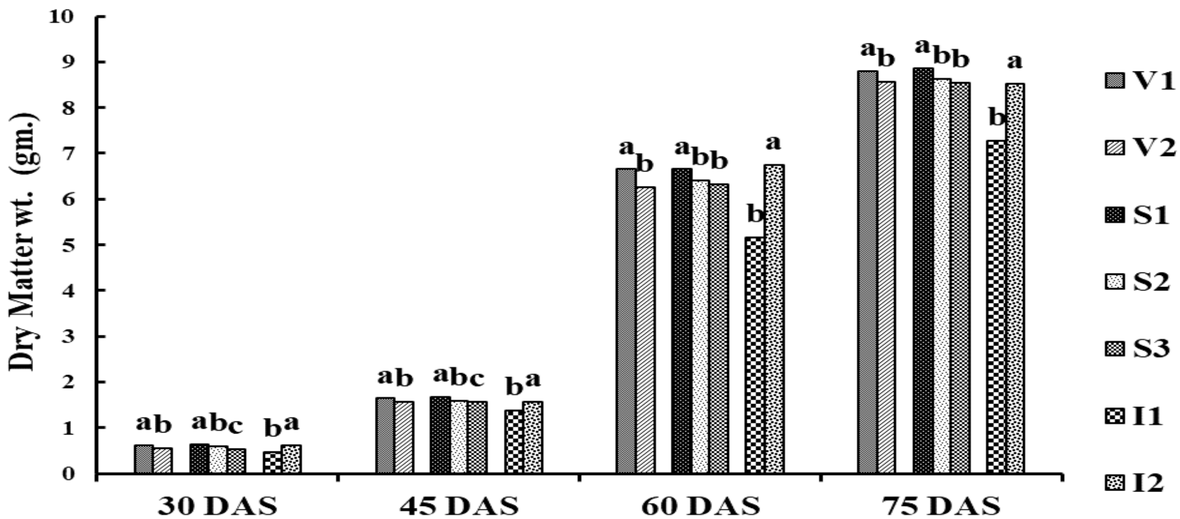
Table.2 Measurement of Stress Degree Day as influenced by different varieties, spacing & irrigation of Garden pea (pooled data of 2017-18 &2018-19)

Treatments		30 DAS	45 DAS	60 DAS	75 DAS
V1(Azad Pea 3)		-1.50	-1.54	-1.90	-1.75
V2(PSM-3)		-1.48	-1.04	-1.43	-1.31
SEm(±)		0.16	0.16	0.07	0.09
CD at 5%		NS	NS	0.21	0.26
S1(40×15)		-1.97	-2.05	-2.51	-2.13
S2(35×10)		-1.52	-1.43	-1.96	-1.66
S3(30×5)		-0.98	-0.40	-0.52	-0.80
SEm(±)		0.20	0.19	0.09	0.11
CD at 5%		0.57	0.56	0.26	0.31
I1(Only at critical stages)		0.19	-0.19	-0.58	-0.44
I2(at 10 days interval)		-3.17	-2.39	-2.75	-2.63
SEm(±)		0.16	0.16	0.07	0.09
CD at 5%		0.47	0.46	0.21	0.26
V×S	SEm(±)	0.28	0.27	0.13	0.15
	CD at 5%	NS	NS	NS	NS
V×I	SEm(±)	0.23	0.22	0.10	0.12
	CD at 5%	NS	0.65	0.30	0.36
S×I	SEm(±)	0.28	0.27	0.13	0.15
	CD at 5%	0.81	0.79	0.37	NS
V×S×I	SEm(±)	0.39	0.38	0.18	0.21
	CD at 5%	NS	NS	NS	NS

Table.3 Influence of different varieties, spacing & irrigation on green pod/ plant , green seed / pod and green pod yield (t ha^{-1}) and seed yield (t ha^{-1}) of garden pea (pooled data of two years)

Treatments		Green pod $plant^{-1}$	Green seed yield
V1(Azad Pea 3)		14.67	6.03
V2(PSM-3)		13.50	5.47
SEm(±)		0.13	0.04
CD at 5%		0.39	0.10
S1(40×15)		15.75	6.34
S2(35×10)		13.63	5.64
S3(30×5)		12.88	5.28
SEm(±)		0.16	0.04
CD at 5%		0.48	0.13
I1(Only at critical stages)		13.08	5.44
I2(at 10 days interval)		15.08	6.06
SEm(±)		0.13	0.04
CD at 5%		0.39	0.10
V×S	SEm(±)	0.23	0.06
	CD at 5%	0.67	0.18
V×I	SEm(±)	0.19	0.05
	CD at 5%	0.55	0.15
S×I	SEm(±)	0.23	0.06
	CD at 5%	0.67	0.18
V×S×I	SEm(±)	0.33	0.09
	CD at 5%	0.95	0.25

Fig.1 Influence of different varieties, spacing & irrigation on dry matter (gm. /plant) accumulation of Garden pea (pooled data of two years)



* For a given DAS, varieties /spacing/ irrigation levels marked with different alphabets differed significantly

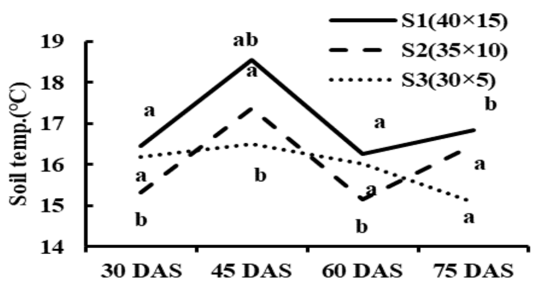


Fig 2 :Effect of different levels of spacing on soil temperature at 5 cm depth

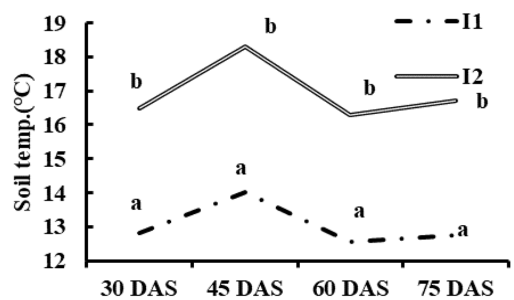


Fig 3 :Effect of different levels of irrigation on soil temperature at 5 cm depth.

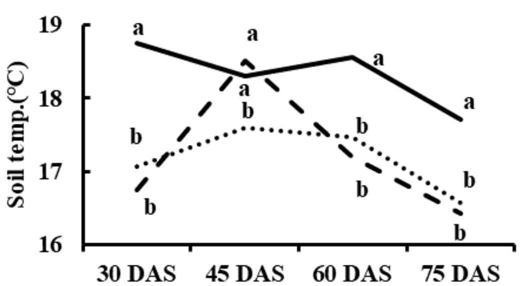


Fig 4 :Effect of different levels of spacing on soil temperature at 15 cm depth

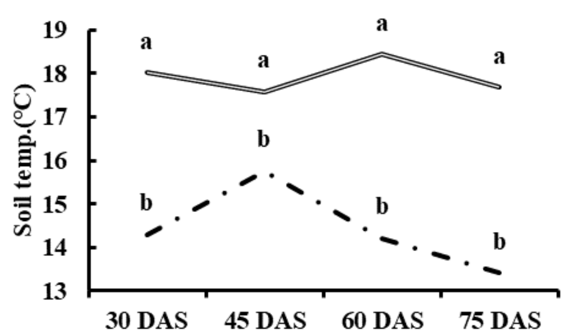


Fig 5 :Effect of different levels of irrigation on soil temperature at 15 cm depth.

Relationship among different micro meteorological parameters and seed yield (t ha^{-1}) of garden pea

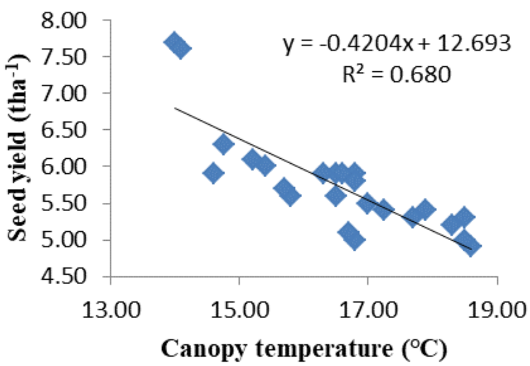


Fig 6: Relationship among canopy temperature (°C) and green seed yield

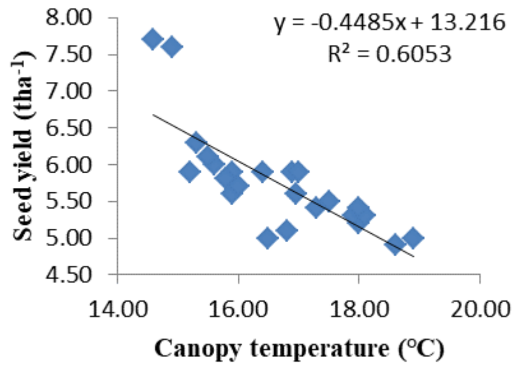


Fig 7: Relationship among canopy temperature (°C) and green seed

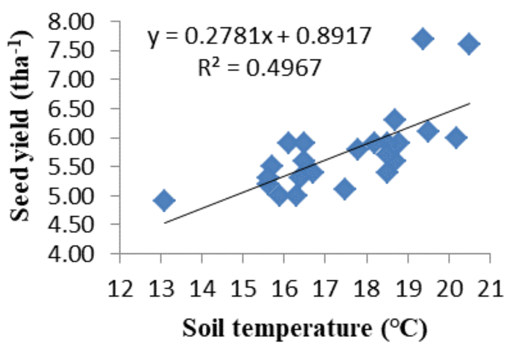


Fig 8: Relationship among soil temperature (°C) at 5 cm depth and green seed yield (t ha^{-1}) at 45 DAS

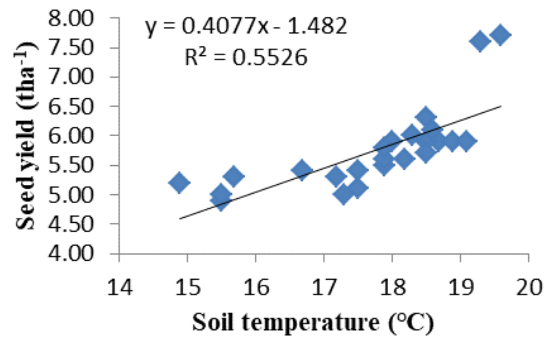


Fig 9: Relationship among soil temperature (°C) at 15 cm depth and green seed yield (t ha^{-1}) at 75 DAS.

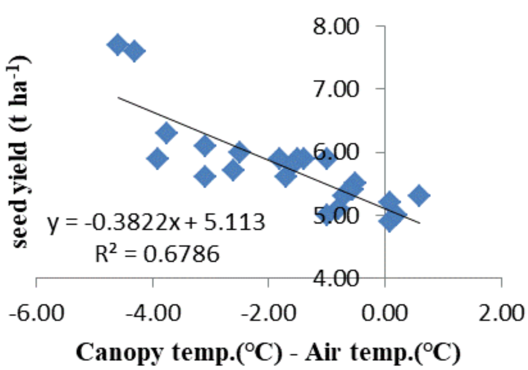


Fig 10: Relationship among Stress degree days and seed yield (t ha^{-1}) at 60 DAS.

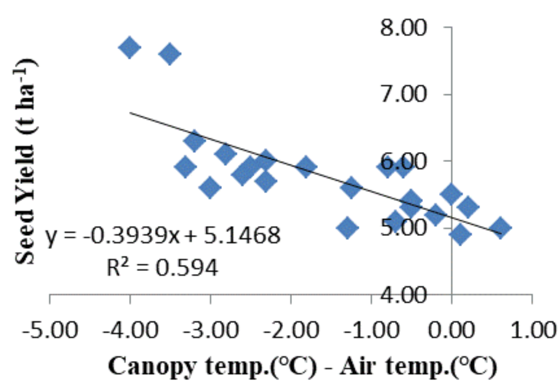


Fig 11: Relationship among Stress degree days and seed yield (t ha^{-1}) at 75 DAS.

Measurement of soil temperature (^{o}C) at 15 cm depth

Experimental results suggested that (Figure 4) soil temperature at 15 cm depth was greatly influenced by different spacing. Effects of spacing have significant effect on soil temperature. Here it is noted that maximum soil temperature (18.55) was at spacing (40x15 cm.) during 60 DAS where minimum soil temperature (16.43) in case of spacing (35x10) at 75DAS. In this experiment two different irrigation levels gives significant effect on soil temperature at 15 cm depth during growing period. Figure 5 shows that more soil temperature in case of I_2 (irrigation at 10 days interval) than I_1 (irrigation applied at critical stages). Critical difference is maximum (1.02) at 45DAS and minimum (0.53) at 60DAS.

Measurement of crop canopy temperature (°C)

It has been observed that crop canopy temperature changed during different time interval based on canopy architecture. As per analysis (table 1) variety PSM 3 shows more canopy temperature than variety Azad pea 3 throughout the growing period and there have significant difference in between varieties and canopy temperature, it must be due to different physiological characters of canopy development of two variety. The temperature regime on pea significantly influenced plant physiological processes (Sakalauskiene *et al.*,) which support our experimental results. It is evident from the data that different spacing schedule significantly influences the canopy temperature. Spacing 30x5 cm. (S_3) showed more canopy temperature followed by S_2 and S_1. Maximum treatment differences was observed 0.38 at 45 DAS. Same result was founded by Kaur, K (2016) that the canopy temperature was significantly higher in 45 cm row spacing than wider row spacings (75 cm and 90 cm) but it was at par with 60 cm and 50 cm row spacing. In this experiment two levels of irrigation were applied in the experiment and these two levels of irrigation shows significant effect on crop canopy temperature. It is noted that in case of I_1 crop shows maximum canopy temperature than I_2 throughout the growing period. At 45 DAS crop shows maximum critical difference (0.31) followed by 30, 60 & 75 DAS. With the increase of irrigation amount, crops rarely suffer from water stress and grow better (such as having a denser canopy), so they have higher canopy transpiration rates and latent heat fluxes which finally resulted in more heat lost, therefore, the transpiration cooling effect is more, and then presented lower canopy temperatures (Hou, Mengjie, *et al.*, 2019). Among all interaction table 1 showed that interaction between variety and spacing have significant effect at 30 DAS (0.34), 60 DAS (0.20) and 75 DAS (0.22). Interaction between variety and irrigation has significant effect at 45 DAS (0.44), 60 DAS (0.16) and 75 DAS (0.18). Interaction between spacing and irrigation also showed significant difference at 30 DAS (0.34), 45 DAS (0.53), 60 DAS (0.20) and 75 DAS (0.22). And three factor interaction also significant effect at 30, 60 and 75 DAS.

Measurement of Stress Degree Days

A stress degree day was calculated by subtracting air temperature from canopy temperature (CT-AT). More negative value indicates that there is less stress. Table 2 shows that two different varieties have significant effect on stress degree days at 60 and 75 DAS with critical difference at 5% level 0.21 and 0.26 respectively. Table shows that closed spaced plants S_3 (30×5 cm) were faced more stress followed by S_2 and S_1. Critical difference at 5% level was more at 30 DAS (0.57) followed by 45 DAS (0.56), 75 DAS (0.31) and 60 DAS (0.26) due to different levels of spacing. Plants, irrigated 10 days intervals (I_2) rarely suffer from water stress than the plants irrigated only critical stages. So in case of I_2, plants have higher canopy transpiration rate which reduce canopy temperature. Interaction between variety and irrigation showed significant effect at 45, 60 & 75 DAS. Interaction between spacing and irrigation also had significant effect during different growth stages. To check the stress, time specific irrigation is necessary during different phonological stages as well as reproductive stages with optimum population level. Same result was found by Stoker. R. (1974) that stress in vegetative phase caused slight stunting of plant growth suffered from abscission and had slightly fewer pods on them.

Number of green pod per plant

Data presented in the table 3 indicates that two different variety definitely influenced number of green pods per plant. Number of pods per plant is more for V_1 i.e. 15 (14.67) than V_2 i.e. 14 (13.50). The treatment effects possess 0.39 as their treatment difference value. Concerning Pods per plant, it was significantly influenced due to plant spacing. Higher number of pods per plant (15.75) was obtained at spacing of 40×15 cm while the lowest number (12.88) was gained at spacing 30×5 cm. So number of pods per plant increasing with decreasing plant density, it was supported by Sharma, S.K., (2002) and found that a reduction in the plant population significantly increases the number of pods per plant. Two different levels of irrigation had significant effect on number of pods per plant, CD value at 5% level 0.39. Table 3 showed that more number of pods in case of I_2 i.e. 15 (15.08) than I_1 i.e. 13(13.08). Stoker *et.al* (1975) reported that the numbers of pods per plant and peas per pod, analysed as a main effect, were increased by irrigation.

Green seed yield (t ha^{-1})

Table shows that variety Azad pea 3 variety produces 6.03 t ha^{-1} and while PSM-3 variety produce 5.47 t ha^{-1} of green seed. Spacing with different row and plant arrangement produces 6.34 t ha^{-1}, 5.64 t ha^{-1} at 5.28 t ha^{-1} at 40x15 cm, 35x10 cm, 30x5 cm spacing respectively which indicate that the wider spacing produce more seed yield compare to others. Critical values 0.13 at 5% level of significance support the findings. The same result was obtain by Bleasdale & Thompson (1963) and reported that by tested plant densities from 43.1 to 161.5 plants m^{-2} and found yield was highest at the lowest density. The relationship between two levels of irrigation with yield of green seed is clearly understood by the treatment difference value 0.10. In this case I_1 (irrigation applied only critical stages) produces 5.44 t ha^{-1} and I_2 (irrigation applied 10 days interval) produces 6.06 t ha^{-1} of green seed yield by which it can be recommended that by applying irrigation at few days interval there is a chance of increasing yield of field pea. The increase in optimum plant population density with irrigation was associated with increases in the number of peas/pod and pea weight (White *et. al*). Among all interaction V×S, S×I and V×S×I showed significant variance between irrigation and green pod yield.

Micrometeorological parameters (viz. canopy temperature, soil temperature), growth attributes and yield of pea had been significantly affected by the treatment combinations i.e. Variety, Spacing and Irrigation. Two different varieties had an important role on no. of pods per plant where V_1 provided more pods per plant (14.67) than V_2 (13.50). Green seed yield of variety V_1 was more than V_2. Three spacing had pronounced effect on green seed yield, S_1 had maximum yield (6.34 t ha^{-1}) followed by S_2 (5.64 t ha^{-1}) and S_3 (5.28 t ha^{-1}). Plants which were irrigated only at critical stages (I_1) faced some stress situation. So under I_1, number of pods, number of seeds per pod and total yield were lesser than those irrigated at 10 days intervals (I_2). All the selected factors played pivotal role in growth and development of garden pea as well as in micro climatic modification.

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