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Effect of irrigation scheduling and nutrient management on yield, water use efficiency and economics in garden pea (*Pisum sativum* L.)

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Abstract
A field experiment was carried out at Palampur during the rabi season of 2017-18 with 12 treatment combinations of three irrigation levels (I1: Irrigation at 15 days interval at 0.8 CPE Cumulative pan evaporation), I2: Irrigation at 15 days interval at 0.6 CPE and I3: Rainfed) and four nutrient management practices (F1:100% NPK through inorganic sources, F2:10 t FYM + Rhizobium + Jeevamrit at 21 days interval, F3: 5 t FYM +50% NPK through inorganic source and F4:Zero budget farming (seed treatment with Bijamrit + Jeevamrit at 21 days interval) and control (Recommended package of practice + flood irrigation at 10 days interval). Water use efficiency (WUE) was significantly higher under rainfed condition. The higher yield attributes, yield, WUE and net returns were obtained with an irrigation.

Keywords: Irrigation scheduling, nutrient management, water use efficiency, economics, pea

Introduction

Garden pea (Pisum sativum L.), a member of the family Fabaceae, is one of the most important cool-season vegetable crops grown worldwide. In India, it is cultivated over an area of about 5,46,000 ha with an annual production of 5.452 million tonnes (Anonymous, 2017) [1]. It occupies a position of considerable worth in the agricultural economy of the country. Being a leguminous crop, it enriches the soil by fixing atmospheric nitrogen in the soil and provides a cover to the land, thus restricting soil erosion. The pea crop is grown both under rainfed and irrigated conditions of the country and the main sowing seasons are October-November in plains and March- June in higher hills. This coincides with the rabi season when the country receives very less rains and the crops are dependent upon supplement irrigations.

With the increasing demand for other sectors, the availability of water for agriculture is decreasing. Hence, increasing agriculture water productivity through agronomic manipulations and technological interventions is the need of the hour. The water productivity in Indian agriculture is very low because of the prevalence of traditional surface irrigation methods accounting for many losses. Pressurized micro-sprinkler irrigation is one method where controlled irrigation is possible with minimum losses of irrigation water. Along with the micro-irrigation technology, irrigation scheduling is also one of the most effective tools to preserve water which includes deciding the time and quantity of water as per the need of the crop (Pachore *et al*., 2018) [21].

The scarce available water from irrigation or rainfall needs to be retained in the soil for subsequent use by the crop, and here the water holding capacity plays an important role. The organic amendments influence the soil fertility through its effect on water holding capacity of the soil (Bulluck *et al*., 2002; Gopinath *et al*., 2008) [8, 15], as the spongy structure of the organic matter bind the water and inorganic molecules, as a consequence the water evaporation slows down. In addition to this, organic amendments feed the soil microbes that release the nutrients (Frankenberger and Dick 1983; Bulluck *et al*., 2002; Dubey *et al*., 1999) [13, 8, 10] and sustain crop productivity (Jaipaul *et al*., 2011) [18]. Thus a strong relationship exists between the nutrient supply and water availability as they complement each other.

To optimize the water use and improve the water use efficiency, integration of micro-irrigation with nutrient management practices hold promise not only for crop and soil productivity sustenance but also for the environment safety under resource scarcity. Hence, an effort was made to study the effect of different irrigation levels and nutrient management practices on the root growth, productivity, economics and water use efficiency in pea.

Materials and Methods

The field experiment was conducted at the Water Management Farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, (32o 06´ 39.1´´ N latitude and 76o 32´ 10.5´´ E longitude; 1290 m above mean sea level) during rabi season of 2017-18. The total rainfall received during the crop season (November 2017 to March 2018) was 201.8 mm. The mean relative humidity varied from 34.0 to 67.4 per cent. The mean daily evaporation during crop season was about 2.55 mm day-1 with a maximum of 4.80 mm per day. Treatment combination consisting of three irrigation levels (I1: Irrigation at 15 days interval at 0.8 CPE, I2: Irrigation at 15 days interval at 0.6 CPE and I3: Rainfed) and four nutrient management practices (F1: 100% NPK through inorganic sources, F2: 10 t FYM +Rhizobium+ Jeevamrit at 21 days interval, F3: 5 t FYM +50%NPK through inorganic source and F4: Zero budget farming (seed treatment with Bijamrit + Jeevamrit at 21 days interval) and control (Recommended package of practice + flood irrigation at 10 days' interval). Azad P1 variety of garden pea was sown at a spacing of 30 cm x 10 cm. A recommended dose of 40:60:60 kg ha-1 NPK was applied through urea, SSP and MOP. Whole inorganic nutrients as per treatment were applied at the time of sowing. The FYM was applied 15 days before sowing @10 t and 5 t in F2 and F3 treatments, respectively. Prior to sowing, seeds of peas were treated with Rhizobium @ 5g kg-1 and Bijamrit @ 10 ml kg-1 of seeds in F2 and F4 treatments, respectively.

Seeds of treatments F1 and F3 were pre-soaked in water for better germination. Before sowing, the soil was drenched with 10% Jeevamrit @ 500 l ha-1 in the plots imposed with treatments F2 and F4. Again, 10% Jeevamrit @ 500 l ha-1 was applied by drenching at 21 days interval on treatments F2 and F4 during the whole cropping season. Similarly, irrigation scheduling was done based on the CPE ratio. Irrigation requirement was calculated by taking into account the difference of actual evaporation and rainfall (only positive values) and multiplying the cumulative average evaporation minus actual rainfall value with CPE ratios. The irrigation was applied through the micro-sprinkler system at an interval of 15 days which consists of three micro-sprinklers per plot, each having a wetting diameter of 1.8 m. In 'Control' treatment, 5 cm deep flood irrigation was applied at every 10 days interval or was scheduled according to the rainfall occurrence. A total of thirteen (3 x 4 + 1 = 13) treatment combinations were laid out in Randomized Block Design (Factorial) with three replications. Yield and different yield contributing characters were recorded. Pods were counted at each picking from randomly selected five plants from each plot. The shelling percentage was calculated as follows:

$$\text{Shelling percentage (\%)} = \frac{\text{Green pea seed weight}}{\text{Green pod weight}} \times 100$$

The green pod yield per hectare was calculated on per plot basis as per the following formula:

$$\text{Yield (q ha}^{-1}\text{)} = \frac{\text{Yield (kg/plot)}}{\text{Area of the plot (m}^2\text{)}} \times 100$$

For the study of various root parameters viz., root length, root volume and root weight root samples were taken with a metal core from 0-0.30 m soil depth at harvest and processed per the procedure given by Bohm (1979) [7]. Sampled roots were used to determine the volume of the root by displacement method (Misra and Ahmed 1987) [20] and expressed in cm3. Relative leaf water content (RLWC) in experimental crop plants was computed as per the method given by Weatherly (1950) [29]:

$$\text{RLWC} = \frac{\text{Fresh weight} - \text{Oven dry weight}}{\text{Fully turgid weight} - \text{Oven dry weight}} \times 100$$

WUE (kg /ha-mm^{-1}) was computed as = Pea pod yield (kg ha^{-1})/Total water use (ha-mm)

Economics of treatments was worked out based on the cost of all operations, inputs and outputs on the prevailing market rates. All the data recorded during the course of investigation were subjected to Analysis of Variance as described by Gomez and Gomez (1984) [14] for using Randomized Block Design at 5 percent level of significance.

Results and Discussion

Yield attributes and Yield

Among different irrigation levels, irrigation at 15 days interval at 0.8 CPE (I1) had a significantly higher number of pods plant-1, pod weight plant-1, shelling percentage, seed weight pod-1 and green pod yield, which was followed by irrigation at 15 days interval at 0.6 CPE (I2) for these traits (Table 1). Rainfed treatment (I3) resulted in the lowest values of all the aforementioned parameters. Availability of water, whether as rain or irrigation, had been a significant factor influencing pea yield (Farah *et al*., 1988) [12]. Irrigation scheduling based on daily evaporation record provides moisture at the right time and in sufficient quantities, which leads to improvement in dry matter accumulation and yield attributes because of better availability of moisture and nutrients during the crop growth. The results conform with Kassab *et al*., (2012) [19] and Patel *et al*., (2012) [22] who also reported a beneficial effect of irrigation on pea crop yield.

Table 1: Effect of irrigation levels and nutrient management practices on yield and yield attributes

Treatment	Number of pods plant^{-1}	Pod weight plant^{-1}	Shelling per cent	Seed weight pod^{-1}	Green pod yield (q ha^{-1})
Irrigation levels					
I_1	11.38	49.91	54.09	2.71	42.93
I_2	10.21	46.34	52.19	2.31	37.02
I_3	9.49	43.82	51.06	2.27	28.50
SE(m±)	0.28	0.68	0.46	0.06	0.82
CD (P=0.05)	0.81	1.98	1.33	0.17	2.39
Nutrient management practices					
F_1	10.03	42.71	51.68	2.32	33.94
F_2	13.36	59.18	56.52	2.77	43.68

F_3	10.45	51.18	54.26	2.68	39.21
F_4	7.59	33.69	47.33	1.95	27.77
SE(m±)	0.32	0.78	0.53	0.07	0.94
CD (P=0.05)	0.94	2.29	1.54	0.19	2.76
Control V/S Others					
Control	11.33	47.12	51.77	2.99	39.65
Others	10.36	46.69	52.45	2.43	36.15
SE(m±)	0.41	1.00	0.67	0.08	1.20
CD (P=0.05)	NS	NS	NS	0.25	NS

I_1: Irrigation at 15 days interval at 0.8 CPE **I_2:** Irrigation at 15 days interval at 0.6 CPE **I_3:** Rainfed
F_1: 100% NPK through inorganic sources practices **F_2:** 10 t FYM +*Rhizobium*+ *Jeevamrit* at 21 days interval **F_3:**5 t FYM +50%NPK through inorganic source **F_4:** Zero budget farming (*Bijamrit* at sowing+ *Jeevamrit* at 21 days' interval)
Control: Recommended package of practice + flood irrigation at 10 days interval

Among the different nutrient management practices, 10 t FYM +Rhizobium+ Jeevamrit at 21 days interval (F2) resulted in a significantly higher number of pods plant-1, pod weight plant-1 and green pod yield. However, the application of 5 t FYM +50% NPK through inorganic source (F3) was statistically at par with F2 for shelling per cent and seed weight pod-1. Significantly lower values for all the parameters were recorded with zero budget farming practice (F4). The beneficial effect of organic manure on yield attributes and yield may be due to supply of plant nutrients, both macro and micro, as well as improvement in physical, chemical and biological properties of soil (Dutt *et al*., 2003) [11] which lead to a significant increase in vegetative growth, better availability and translocation of nutrients (Singh *et al*. 2009). Atmospheric nitrogen fixation by Rhizobium and the favorable condition in the soil due to biofertilizers and higher organic matter leads to soil N's mineralization leading to a build-up of higher available N (Ansari and Kumar 2010 and Ansari and Jaikishun, 2011). Moreover, jeevamrit, which contained 2.26, 0.121, 0.463 N, P and K respectively (approximately) sprayed at 21 days interval supplied the required plant nutrients during the whole growing season, thereby significantly increased the yield and yield attributes.

Table 2: Effect of irrigation and nutrient management practices on root growth and water use efficiency (WUE)

Treatment	Root weightplant^{-1} (g)	Root volumeplant^{-1} (cm^3)	Root length plant^{-1} (cm)	RLWC (1st Irrigation)	RLWC (5th Irrigation)	WUE (kg ha^{-1} mm^{-1})
Irrigation level						
I_1	0.64	2.05	16.41	82.84	80.44	16.49
I_2	0.47	1.88	19.70	81.76	78.43	17.02
I_3	0.30	1.51	17.84	76.10	75.61	31.91
SE(m±)	0.02	0.13	0.36	0.46	0.88	0.47
CD (P=0.05)	0.07	0.37	1.06	1.35	2.56	1.37
Nutrient management practice						
F_1	0.48	1.73	17.99	78.30	75.39	20.74
F_2	0.60	1.97	19.61	82.32	80.30	26.82
F_3	0.51	2.24	17.87	82.86	82.92	23.63
F_4	0.30	1.32	16.47	77.45	74.03	16.03
SE(m±)	0.03	0.15	0.42	0.53	1.01	0.54
CD (P=0.05)	0.08	0.43	1.23	1.56	2.96	1.58
Control V/S Others						
Control	0.50	2.10	16.51	82.02	80.83	6.61
Others	0.47	1.81	17.99	80.23	78.16	21.81
SE(m±)	0.03	0.19	0.54	0.68	1.29	0.69
CD (P=0.05)	NS	NS	NS	NS	NS	2.01

I_1: Irrigation at 15 days interval at 0.8 CPE **I_2:** Irrigation at 15 days interval at 0.6 CPE **I_3:** Rainfed
F_1: 100% NPK through inorganic sources practices **F_2:** 10 t FYM +*Rhizobium*+ *Jeevamrit* at 21 days interval **F_3:**5 t FYM +50%NPK through inorganic source **F_4:** Zero budget farming (*Bijamrit* at sowing+ *Jeevamrit* at 21 days' interval)
Control: Recommended package of practice + flood irrigation at 10 days interval

Yield attributes and yield did not differ significantly between control practice of recommended NPK and flood irrigation at 10 days interval and other treatment combinations. This may be due to easy availability in control practice which matched the demand. The treatment combinations on the other hand have economized on the inputs and water specifically and that was reflected in water use efficiency.

Root growth

Among different irrigation levels, significantly higher root weight and volume plant-1 were recorded when irrigation at 15 days interval of 0.8 CPE (I1) was given (Table 2). However, root volume plant-1 in treatment (I1) was statistically at par when irrigation at 15 days interval at 0.6 CPE (I2) was provided. Rainfed treatment (I3) resulted in significantly lower root weight plant-1. Significantly higher and lower root length plant-1 was recorded under (I2) and (I1), respectively. Water stress (too little water for root growth) limits root growth as water stress induces mechanical impedance (soil that is too hard for roots to penetrate rapidly) which is the primary cause of poor root system growth and development (Bengough *et al*. 2010) [6]. There is a strong interplay between the strength and water content of the soil. The significantly higher root weight plant-1 and root volume plant-1 under irrigation at 15 days interval at 0.8 CPE (I1) may be because moisture availability was more in the treatments, which decreased the mechanical impedance and soil moisture tension. The optimum distribution of root length depends mainly on the distribution of water in the soil. In dry seasons plants may require long main root axes to access water stored deep in the soil profile, while if abundant water is available, only a small fraction of the root length may suffice (Bengough *et al*., 2006) [5].

Among nutrient management practices, significantly higher root volume plant-1 was recorded under the treatment F3, which was statistically at par with the treatment F2. Significantly higher and lower root length plant-1 and root weight plant-1 were recorded under the treatments F2 and F4, respectively. Patel *et al*., (2000) [23] reported that farmyard manure improves the soil's physical properties, with a reduction in bulk density and increase the water retention of soil. Hence, the significantly higher root development characteristics in F2 treatment may be due to the more water retention by FYM around root area which induce the formation of the humic acid and thereby leads to stimulation of root growth (initiation and proliferation of root hair) and that increased root biomass (Chen and Aviad, 1990) [9]. Better roots help the plant utilize water from deeper layers (Halvin *et al*., 2003) [17].

The treatment combination of irrigation and nutrient management practice did not differ significantly with respect to control practice for the growth parameters.

Relative leaf water content

The RLWC is a measure of water present in the leaf tissue and the plant water potential. It is mediated by both soil matric suction and solar radiation. The relative leaf water content before 1st and 5th irrigation were significantly highest with irrigation level I1. Significantly higher relative leaf water content under irrigation level I1 may be due to no or mild water stress that produced higher root mass and volume to extract moisture in soil profile. The rainfed treatment (I3) resulted in significantly lower relative leaf water content. Significantly lower relative leaf water content in I3 treatment may be due to the unavailability of water in soil or root system, which could not compensate for water loss by transpiration. Under severe stressed treatment (I3) the root tips lost the capacity to extract soil moisture and resulted in lower RLWC due to continuous skipping of irrigation cycles (Sampathkumar *et al*., 2013) [24].

The relative leaf water content before 1st and 5th irrigation was significantly higher among different nutrient management practices under F3 and F2 treatments. Significantly lower relative leaf water content was observed with zero budget farming practices (F4) and was statistically at par with the treatment F1. The RLWC is a function of several factors like plant water potential, water retention capacity of soil and plant and excised leaf water loss rate. The improvement of water holding capacity with organic amendments (Bulluck *et al*., 2002) [8] may have made moisture available for long, hence higher leaf water potential was in F3 treatment. The relative leaf water content in control practice remained at par with other treatment combinations which showed that a similar environment was experienced for root development

Water use efficiency (WUE)

Significantly higher water use efficiency was obtained under rainfed condition (I3) followed by irrigation at 15 days interval at 0.6 CPE (I2) and irrigation at 15 days interval at 0.8 CPE (I1). Higher water use efficiency in rainfed treatment may be because of lower values both for yield and water use. Although with irrigation, yield increased but the water used was also higher, which brought down the efficiency. Saroch *et al*. (2014) also reported higher water use efficiency under a lower irrigation level of 0.6 CPE in garden pea. They also reported higher water use efficiency in pea crop under organic nutrient management practices.

Among different nutrient management practices, significantly higher water use efficiency was recorded under the treatment having 10 t FYM + Rhizobium + Jeevamrit at 21 days interval (F2) followed by the treatments 5 t FYM + 50% NPK through inorganic source (F3) and 100% NPK through inorganic sources practices (F1). Significantly lower water use efficiency was under zero budget farming practices (F4). The higher water use efficiency under F2 treatment may be due to more water retention by FYM, resulting in moisture available for long which leads to more leaf water potential, leaf water content and enhanced WUE (Shi *et al*. 2014 and Bai *et al*. 2003) [28]. Again farmyard manure reduces soil bulk density so that the roots freely extend to scavenge.

Table 3: Effect of irrigation levels and nutrient management practices on yield and yield attributes

Treatment	Cost of Cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	Returns per unit water use (₹ m^{-3})	B:C
Irrigation levels					
I_1	38210	128781	90571	30.53	2.38
I_2	37580	111069	73489	37.61	1.94
I_3	35060	85494	50434	72.33	1.43
SE(m±)		2453	2453	2.03	0.07
CD (P=0.05)		7160	7160	5.91	0.20
Nutrient management practices					
F_1	34488	101833	67345	40.42	1.94
F_2	44978	131033	86056	62.49	1.91
F_3	35013	117617	82604	59.46	2.34
F_4	33323	83308	49986	24.92	1.48
SE(m±)		2832	2832	2.34	0.08
CD (P=0.05)		8268	8268	6.83	0.23
Control V/S Others					
Control	45096	118950	73855	12.31	1.64
Others	36950	108448	71498	46.82	1.92
SE(m±)		3611	3611	2.98	0.10
CD (P=0.05)		NS	NS	8.70	NS

I_1: Irrigation at 15 days interval at 0.8 CPE **I_2:** Irrigation at 15 days interval at 0.6 CPE **I_3:** Rainfed

F_1: 100% NPK through inorganic sources practices **F_2:** 10 t FYM +*Rhizobium*+ *Jeevamrit* at 21 days interval **F_3:**5 t FYM +50%NPK through inorganic source **F_4:** Zero budget farming (*Bijamrit* at sowing+ *Jeevamrit* at 21 days' interval)

Control: Recommended package of practice + flood irrigation at 10 days interval

The treatment combination of irrigation levels and nutrient management practices resulted in high water use efficiency compared to control (Flood irrigation at 10 days interval with the recommended practice of 100 % NPK + FYM). This could be attributed to the fact that under control practice more frequent irrigation was applied. This extra water does not contribute to an incremental increase in yield and thus had lower water productivity.

Economics

Among different irrigation levels, higher gross return (₹1,28,781 ha-1), net return (₹90,571 ha-1) and B:C (2.38) were obtained with an irrigation level of 0.8 CPE (I1) (Table 3). The rainfed treatment (I3) had the lowest values of all the aforementioned economic parameters. However, in case of returns per unit water use, highest values (₹72.33 m-3) was obtained under rainfed condition (I3) followed by the returns of ₹ 37.61 m-3 and ₹ 30.53 m-3 water use for the irrigation level of 0.6 CPE (I2) and 0.8 CPE (I1), respectively. Sarkar *et al*. (2016) opined that a higher cost of cultivation was involved with frequent irrigation.

The application of 10 t FYM + Rhizobium + Jeevamrit (F2) gave significantly higher gross and net returns among different nutrient management practices. However, the highest B:C (2.34) was obtained with the application of 5 t FYM + 50% NPK through inorganic source (F3). Gopinath *et al*. (2009) [16] also obtained higher gross returns under organics in pea crop. Sharma and Verma (2011) obtained higher net returns in rajmash under Rhizobium inoculation and FYM application.

Control resulted in a higher (₹ 45,096) cost of cultivation when compared to the other treatments. In the control treatment, frequent irrigation and nutrient management practices involving FYM with a full dose of inorganic nutrients added to the cost.

Conclusion

Irrigation at 0.8 CPE proves to be significantly superior which gave higher green pea yield, net returns and B:C ratio, but in contrast, a lower water use efficiency was observed. Hence, irrigation at 0.6 CPE can be the next option under limited water supply. Regarding nutrients, the application of 10t FYM + *Rhizobium* + *Jeevamrit* gave higher pod yield, net returns and B:C ratio, and higher water use efficiency was best followed by nutrient management practice of 5t FYM + 50% NPK through inorganic source.

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