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Irrigation methods and integrated nutrient management leading to improved growth, production and nutrient uptake of vegetable pea (*Pisum Sativum* L.)

AASHU RAJPUT*[1], K.P. RAVERKAR[1], GURVINDER SINGH[2], NAVNEET PAREEK[1], RAMESH CHANDRA[1] AND POOJA NAIN[1]

Department of Soil Science, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar- 263145, Uttarakhand, India

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ABSTRACT

In India, Vegetable Pea is important winter crop of northern-western Himalayan region. The identification of suitable irrigation method responding well to organic management is the key to achieve higher production. Organic manures help in increasing crop productivity, soil health and nitrogen utilization efficiency. Drip irrigation is controlled way of irrigation with minimum losses of water. Field experiment was directed during Rabi season- 2020 at Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar to test the hypothesis that use of balanced fertilization conjointly with organic manures under drip irrigation would result in improved productivity of vegetable pea and improved soil health. The experiment comprised of two irrigation methods (drip and flood) and six nutrient management combinations replicated three times in split plot design. Drip irrigation supported significantly higher values of growth and yield attributes, pod yield, nutrient content and its uptake compared to flood irrigation. Drip irrigation produced 17.0 percent higher pod yield over flood irrigation. Integrated nutrient management practice (RDF + FYM @2.5 t/ha + vermicompost @ 1t/ha) under drip irrigation significantly enhanced the growth and yield attributes, pod yield, nutrient content and uptake of nutrients. Application of RDF + FYM @2.5 t/ha + vermicompost @ 1t/ha under drip and flood irrigation supported 30.8 and 23.8 percent higher pod yield compared to RDF alone under drip and flood irrigation, respectively.

Keywords: Drip irrigation; Flood irrigation; integrated nutrient management; Vegetable pea.

INTRODUCTON

Vegetable pea (*Pisum sativum* L.) is a winter season legume crop cultivated in various states of India including Uttarakhand. Early maturing pea fits well between the crop rotations of rice- spring maize, rice- late sown wheat and rice- sugarcane which can make it very profitable and has a great potential in domestic and export market. It improves the soil fertility status through nitrogen fixation by *Rhizobium leguminosarum* (Singh *et al.,* 2019). In India, vegetable pea occupies 568-thousand-hectare area with production of 5.85 million tons during 2019-20 (Horticulture Statistics division, DAC&FW). Nutrient requirement of vegetable pea is mainly fulfilled through chemical fertilizers with no or meager amount of organic manures. Chemical fertilizers contain concentrated amount of nutrients, which are readily available to plants and are also relatively cost effective in comparison to the organic manures procured from market. But their imbalanced use leads to deteriorated soil health as well as its excess use can cause ground and surface water contamination, loss of nutrients, soil basification or acidification, increase in sensitivity to harmful insects and reductions in communities of useful microbes, such as *Rhizobium*. Farmyard manure (FYM) is most readily available with farmers. Vermicompost is a natural organic product produced by earthworms, eco-friendly and widely prepared by farmers. Vermicompost consists of 1.5- 2.0% N, 0.9-1.7% P and 1.5- 2.5% K; and FYM composition 0.5% N, 0.2% P, and 0.5% K (Thongney *et al.,* 2020**).** Organic manures provide a variety of advantages, including improved nutrient delivery and more readily available soil nutrients due to increased soil microbial activity and improved biogeochemical cycles (Ahmad *et al.,* 2016) besides its role in improvement of physical soil properties. Application of chemical fertilizers or organic manures alone does not sustain the productivity of crop and soil health. However, integration of both has been reported to be superior over their individual application to improve yield, quality and nutrient uptake

** Corresponding author's e-mail – aashurajput.1997@gmail.com*
[1] Department of Soil Science, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar-263145, Uttarakhand, India.
[2] Department of Agronomy, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar-263145, Uttarakhand, India.

(Chaudhary *et al.,* 2018).

In India, irrigated farming has a major role in food production. It is pertinent to mention that, water availability for agriculture is decreasing day by day. Hence, there is a dire need to increase the water productivity with the help of agronomic manipulations and technological interventions. Conventionally, pea is flood irrigated with frequent light irrigations for better performance of the crop (Rao *et al.,* 2016). Water saving in agriculture is the possible solution to handle the problem of climate change and producing more crops per drop of water adopting method(s) of irrigation having minimum losses (Saroch *et al.,* 2015). Considering the above, the present investigation was carried out with the hypothesis that the use of balanced fertilization conjointly with organic manures under drip irrigation would result in improved productivity of vegetable pea and nutrient uptake.

MATERIALS AND METHODS

The field experiment was conducted at Norman Ernest Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology (GBPUA&T), Pantnagar, Udham Singh Nagar, Uttarakhand situated at 29º N latitude and 79.49º E longitude during *Rabi* season of 2020-2021. The experimental site soil was sandy-loam in texture having pH 7.42, organic carbon 0.91%, 109.0kg N/ha, 24.7 kg P/ha and 189 kg K/ha.

The treatments consisted of two irrigation methods i.e., drip and flood, and six nutrient management practices i.e. T_1: Recommended dose of fertilizer (RDF) @ 30:60:30:: N: P_2O_5:K_2O/ha, T_2: RDF + FYM @ 5t/ha, T_3: RDF + FYM @ 2.5t/ha + vermicompost @ 1t/ha, T_4: Vermicompost @ 4.5 t/ha, T_5: FYM @ 10t/ha and T_6: Vermicompost @ 2.5t/ha + FYM @ 5t/ha. The experiment was laid out in split plot design and replicated thrice. Irrigation treatments were assigned to main plot and nutrient management practices to sub plots. Vegetable pea variety "Azad pea-3" was sown in the first fortnight of the November during the study. Seeds were manually drilled in rows spaced 20 cm apart using seed rate @80 kg/ha. In all, there were 36 experimental plots, each measuring 2.4 m x 4.5 m. A buffer space of 1m was maintained between two adjacent plots to avoid interference of one treatment with another plot. In each plot, a total 12 rows were accommodated at a spacing of 20 cm. Drip laterals were installed in the field immediately after sowing of vegetable pea. Laterals were spaced at 40 cm row spacing between two pea rows. Spacing of online drippers was 30 cm having the discharge rate of 2.2 liters per hour (LPH). Control valves were fixed in all the plots to facilitate controlling the water flow as per the treatments.

CPE value of previous three days was multiplied with Pan Coefficient value of 0.7 to apply irrigation on PET basis. Rainfall was subtracted from the CPE. In flood-method pre-sowing irrigation depth of 6 cm was maintained while later on it was 5 cm. and total four irrigations were given using Parshall flume.

Epan= Pan evaporation * K pan (in general taken as 0.7)

Entire dose of recommended P, K and 25% of N dose, as per treatment, were applied as basal through fertilizer NPK (12:32:16) + urea + MOP. The requisite quantity of organic manures in full as basal, on dry weight basis was applied. The observations on various growth, yield and yield attributes were recorded as per standard procedures. Root density of plants was measured with the help of measuring cylinder employing water displacement method. After uprooting and washing, the roots were dipped in a measuring cylinder containing known amount of water. The water displaced by roots was considered to be root volume expressed as g/cm^3. Then, root weight density was calculated by using the formula:

$$\text{Root weight density (g/cm}^3\text{)} = \frac{\text{mass of root}}{\text{volume of root}}$$

Data were analyzed using analysis of variance (ANOVA) with help of OPSTAT software. Analysis of variance of the experimental data was carried out as per split-plot design Gomez and Gomez, (1983). Nutrient uptake in roots, shoots and pods was determined by using the standard procedure employing formula:

$$\text{Nutrientuptake} = \frac{\%Nutrient\ content\ x\ biomass\ or\ pod\ yield\ x\ 1000}{100}$$

RESULTS AND DISCUSSION

Growth parameters

Plant height, dry shoot and root weight, root: shoot ratio, root volume of pea was significantly impacted by irrigation methods, nutrient management practices and their interactions (Table 1). At flowering, plant height and dry shoot weight enhanced significantly with drip irrigation by 5.7 and 29.9% over flood method while at harvest, drip irrigation improved it marginally. Nutrient management practices, only at flowering, significantly improved plant height, highest (51.0 cm) being attained with an application of RDF + FYM @ 2.5t/ha + vermicompost @ 1t/ha (T_3) followed by FYM @ 10t/ha (T5), while application of vermicompost @ 4.5 t/ha resulted (T_4) in lowest (47.90 cm). An application of T_3, at both the stages of plant growth, produced highest shoot dry weight which was greater by 33.9 and 20.6% over vermicompost @ 4.5 t/ha (T_4) and FYM @ 10t/ha (T_5), at flowering and harvest, respectively.

Table 1: Impact of irrigation methods and nutrient management practices on shoot and root attributes of vegetable pea

Treatments	Plant height (cm)		Dry shoot weight (g/plant)		Dry root weight (g/plant)		Root: Shoot ratio		Root Volume (cm^3)		Root density (g/cm^3)		Root weight density (kg/m3)	
	F	H	F	H	F	H	F	H	F	H	F	H	F	H
Drip	49.7	56.0	3.00	15.27	0.117	0.142	0.039	0.009	0.267	1.44	1.07	0.88	8.39	8.95
Flood	47.0	55.3	2.31	15.04	0.122	0.143	0.053	0.010	0.267	1.22	1.20	1.15	7.66	8.08
CD(0.05) I	1.34	NS	0.05	NS	NS	NS	0.006	NS	NS	0.136	NS	NS	0.509	NS
T_1	48.1	56.2	2.48	13.23	0.120	0.134	0.048	0.010	0.253	0.92	1.07	1.08	7.28	7.33
T_2	46.8	54.3	2.83	15.09	0.127	0.145	0.045	0.010	0.290	1.50	1.25	0.86	9.21	8.32
T_3	51.0	57.1	3.20	15.96	0.130	0.144	0.042	0.009	0.277	1.25	1.13	1.05	8.34	9.02
T_4	47.9	56.0	2.39	15.15	0.105	0.146	0.044	0.010	0.267	1.42	1.12	0.99	7.96	8.07
T_5	48.3	54.9	2.39	14.16	0.110	0.143	0.048	0.010	0.260	1.33	1.09	1.10	7.64	9.20
T_6	47.9	55.5	2.65	17.33	0.125	0.145	0.049	0.008	0.253	1.58	1.14	0.99	7.71	9.16
CD (0.05) NM	2.05	NS	0.06	0.76	0.01	0.003	NS	0.001	NS	0.358	NS	NS	0.771	NS
I x NM (I)	3.07	3.97	0.09	1.69	NS	NS	0.008	0.001	NS	NS	NS	NS	NS	NS
I x NM (NM)	2.87	3.72	0.08	2.13	NS	NS	0.008	0.001	NS	NS	NS	NS	NS	NS

** F= Flowering stage and H= At Harvest stage*

Irrigation methods did not influence dry root weight at flowering as well as harvest and root: shoot ratio at harvest, significantly. Nutrient management practices significantly improved the dry root weight as well as root: shoot ratio, at harvest. Flood irrigation improved root density compared to drip irrigation by 12.2% and 30.7% at flowering and harvest, respectively. At flowering, root volume has same value under both irrigation methods, while at harvest drip was superior to flood irrigation. An application of RDF + FYM @ 5t/ha (T_2) and vermicompost @ 2.5t/ha + FYM @ 5t/ha (T_6) resulted in higher root volume (0.290 cm^3 and 1.58 cm^3) at flowering and harvest, respectively. Drip irrigation resulted in 8.4% higher root weight density compared to flood irrigation at flowering as well as at harvest. Nutrient management practices comprising organic and inorganic nutrient sources enhanced root weight density, highest (9.21 kg/m^3 and 9.20 kg/m^3) being produced with RDF + FYM @5t/ha (T_2) and Farm Yard manure @10t/ha (T_5) and while the lowest (7.28 kg/m^3 and 7.33 kg/m^3) in due to RDF @ 30:60:30:: N: P_2O_5: K_2O/ha (T_1), at flowering and harvest stage, respectively.

The effect of inorganic nutrient management practice and/or organic source of nutrients under drip irrigation facilitated higher growth attributes such as plant height, dry matter accumulation in shoots and roots and root volume. Ability of drip irrigation to maintain uniform supply of water in a controlled manner favored the prevailing micro-climate in terms of soil-water-air equilibrium around the crop, facilitating efficient use of nutrients and water by crop plants thus increased plant height and dry matter accumulation (Imamsaheb *et al.,* 2011). The results are in line with the work of (Bhasker *et al.,* 2018) for plant growth. The organic manures such as FYM, vermicompost might have enhanced the friability, bio pore spaces, reduced bulk density, enhanced aggregation of soil particles vis-à-vis microbial activity. Improved physical and biological status of soil would have supported root growth parameters, shoot growth and enhanced photosynthesis leading to accumulation of more carbohydrates increasing overall dry matter accumulation (Fazily and Hunshal, 2010).

Yield attributes

Drip irrigation produced significantly higher number of pods per plant and individual pod weight by 24.4 and 4.4%, respectively, compared to flood irrigation. Nutrient management practices comprising organic and inorganic nutrient sources significantly improved pod number and individual pod weight, highest (10.8/plant and 9.4 g/pod) being produced with application of RDF + FYM @ 2.5t/ha + vermicompost @ 1t/ha (T_3) while lowest were observed due to RDF @ 30:60:30:: N: P_2O_5:K_2O/ha (T_1). The irrigation methods and nutrient management practices influenced individual pod weight significantly (Table 2). Drip irrigation marginally improved pod length over flood irrigation. Nutrient management practice comprising RDF + FYM @ 2.5t/ha + vermicompost @ 1t/ha (T_3) supported highest (9.13 cm) pod length while the lowest (8.68 cm) was due to RDF @ 30:60:30:: N: P_2O_5:K_2O/ha (T_1). Flood irrigation was superior to the drip irrigation supporting 7.4 percent more number of grains per pod compared to drip irrigation (Table 2). Grain weight and shelling percentage of vegetable pea was significantly improved by various treatments *viz.,* irrigation methods, nutrient practices and their interactions. Drip irrigation supported significantly higher grain weight and shelling percentage by 11.2% and 5.9%, respectively, over flood irrigation. Highest grain weight and shelling percentage (3.90 g/pod and 41.37%, respectively) was supported by T_3 while lowest (3.63 g/pod and 40.34%, respectively) was due to RDF @ 30:60:30:: N: P_2O_5:K_2O/ha (T_1) and FYM @ 10t/ha (T_5), respectively.

Table 2: Impact of irrigation methods and nutrient management practices yield attributes and stover yield

	No. of Pods (Per plant)	Individual pod weight (g/pod)	Pod length (cm)	Grain per pod	Grain weight per pod (g)	Shelling %	Pod yield (Mt/ha)	Stover yield (Mt/ha)
Drip	10.2	9.41	8.97	3.78	3.95	41.96	11.48	4.68
Flood	8.2	9.01	8.88	4.06	3.57	39.63	9.81	6.43
CD(0.05) I	0.286	0.026	NS	0.112	0.198	2.09	0.423	0.019
T_1	8.0	8.88	8.68	3.88	3.63	40.81	8.89	5.22
T_2	10.3	9.27	9.11	3.93	3.77	40.72	11.13	5.81
T_3	10.8	9.42	9.13	3.92	3.90	41.37	11.34	6.09
T_4	8.8	9.13	8.90	3.77	3.74	40.89	10.76	5.35
T_5	9.0	9.31	8.99	3.90	3.76	40.34	10.89	5.95
T_6	8.6	9.28	8.71	4.10	3.77	40.63	10.85	4.91
CD (0.05) NM	0.779	0.086	0.142	0.085	0.063	0.532	0.282	0.109
I x NM (I)	NS	0.123	NS	0.146	0.148	1.348	0.504	0.154
I x NM (NM)	NS	0.113	NS	0.147	0.202	2.097	0.520	0.141

Irrigation methods, nutrient management practices and their interactions significantly impacted pod yield of vegetable pea. Highest pod yield more by 17.0 percent was obtained under drip irrigation compared to flood irrigation (Figure 1). RDF+ FYM 2.5t/ha + vermicompost 1t/ha (T_3) application resulted in 27.6 percent increase in pod yield as compared to RDF @ 30:60:30:: N: P_2O_5:K_2O/ha (T_1). Drip irrigation with T_3 produced highest pod yield, pod weight, pod length, pods per plant, whereas the lowest were recorded in flood irrigation in combination with T_1.

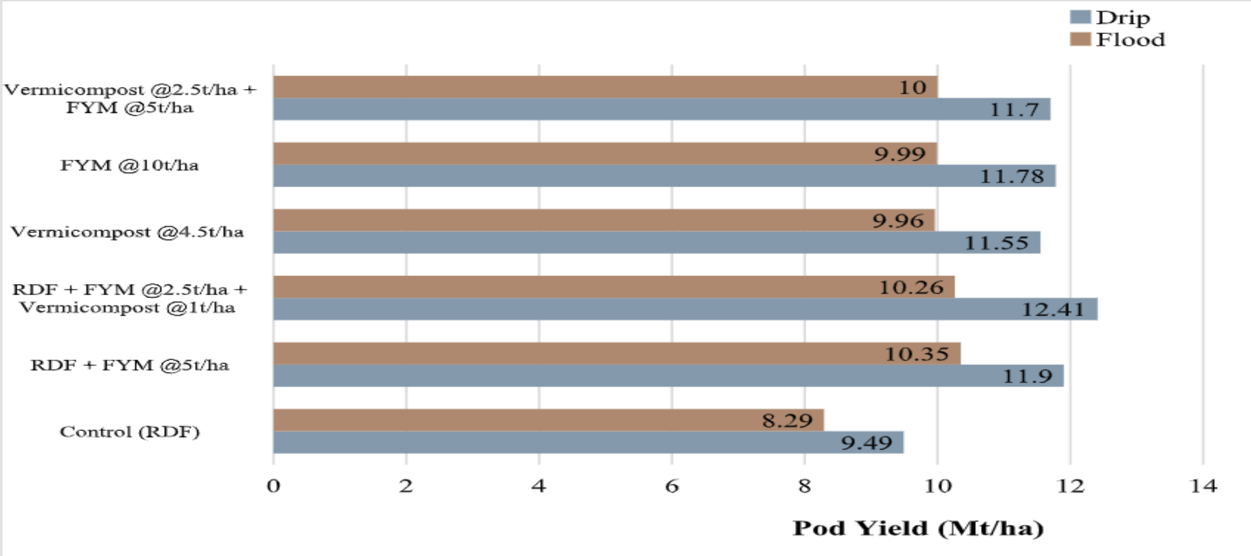

Figure 1: Interaction effect of different irrigation and nutrient management practices on pod yield Mt/ha)

Flood irrigation supported 37.4% higher stover production compared to drip irrigation (Table 2). Nutrient management comprising RDF + FYM @ 2.5t/ha + vermicompost @ 1t/ha (T_3) produced highest stover yield (6.09 Mt/ha) which was higher by 24.0 percent over the application of vermicompost @ 2.5t/ha + FYM @ 5t/ha (T_6). Drip irrigation facilitates conducive moisture regime in between the two irrigation intervals leading to increased N, P and K uptake, enhanced photosynthesis and production of carbohydrates. Accelerated carbohydrate synthesis builds up dry matter accumulation thus leading to greater photosynthates contributing to higher yield attributes. Utilising both organic and inorganic nutrients increased the synergism and synchronisation between nutrient release and plant uptake, leading to higher crop development in terms of yield (Huang *et al.,* 2010). Adequate supply of nutrients through organics and inorganics supplying protoplasmic constituents enhances the cell elongation process increasing the values of attributes contributing to growth and yield (Aktar *et al.,* 2019). Nutrient management practices significantly impacted the yield. INM improved the yield from 21.0 to 27.6% over alone application of synthetic fertilizers (T_1). Lower yield was recorded due to application of RDF (T_1) under flood irrigation probably, due to the low moisture availability in between the two irrigation intervals, reduced infiltration affecting the nutrients movement and absorption by the roots. This in turn affected the chlorophyll content in leaves vis-à-vis photosynthetic activity reflecting in lower yield (Behera *et al.,* 2012).

Nutrient uptake

Nutrient uptake in stover, roots and pods at harvest, was significantly impacted by nutrient management practices and their interactions with different irrigation methods (Table 3). N, P and K uptake by shoot was significantly higher under flood irrigation by 32.5, 37.6 and 21.2 percent compared to drip irrigation, respectively. At harvest, use of RDF + FYM @2.5t/ha + vermicompost @1t/ha (T_3) facilitated significantly highest nutrient uptake in stover (195.80 N, 55.27 P and 54.81K kg/ha) (Table 3).

At harvest, drip irrigation was superior to the flood irrigation improving N, P and K uptake in roots by 28.9, 16.7 and 17.3 percent, respectively. Highest N, P and K-uptake by roots (2.16, 0.45 and 1.23 mg/plant, respectively) was resulted with an application of RDF + FYM @ 2.5t/ha + vermicompost @1t/ha (T_3), vermicompost @ 2.5t/ha + FYM@ 5t/ha (T_6), and T_3 and T_6 respectively. Lowest amount of nutrients were recorded in roots of plants receiving only RDF (T_1). Uptake of N, P and K in pods under drip irrigation, was 46.3, 21.9 and 22.32 percent higher, respectively as compared to flood irrigation. Application of RDF + FYM @2.5t/ha + vermicompost @1t/ha (T_3) supported highest N, P and K uptake in pods (102.64, 32.93 and 39.69 kg /ha, respectively) while lowest N, P and K uptake was observed due to recommended dose of NPK (Table 3).

Table 3: Impact of irrigation methods and nutrient management practices on nutrient uptake in shoots, roots and pods at harvest

Treatments	Stover (kg/ha)			Roots (mg/plant)			Pods (kg/ha)		
	N	P	K	N	P	K	N	P	K
Drip	133.86	35.47	40.02	2.14	0.42	1.22	103.65	29.64	39.89
Flood	177.40	52.12	50.77	1.66	0.36	1.04	70.86	24.31	32.61
CD(0.05) I	8.51	1.19	0.79	0.02	0.004	0.01	0.58	0.05	7.27
T_1	117.18	29.69	39.69	1.42	0.29	0.86	62.78	21.63	33.01
T_2	153.06	45.81	46.17	1.83	0.42	1.18	93.80	21.41	37.68
T_3	195.80	55.27	54.81	2.16	0.45	1.23	102.64	32.93	39.69
T_4	156.45	44.41	45.53	1.82	0.41	1.07	96.16	28.20	36.74
T_5	166.40	47.20	46.38	2.04	0.41	1.20	91.62	29.50	36.09
T_6	144.86	40.39	39.78	2.14	0.41	1.23	76.55	28.18	34.28
CD (0.05) NM	4.21	1.48	1.06	0.02	0.004	0.003	0.63	0.25	1.34
I x NM (I)	8.36	2.27	1.62	0.03	0.01	0.01	0.99	0.35	3.69
I x NM (NM)	9.36	2.16	1.53	0.03	0.01	0.01	0.95	0.32	7.24

Water availability in root zone during plant growth is one of the most important factors governing the growth of root and acquisition of nutrients from soil. The higher values of nutrient uptake under drip irrigation could be assigned to the continuous and sustained supply of moisture maintaining the congenial conditions for the growth of roots and microbial activities. Under drip irrigation, preferential reception of water from suitably moist soil may have encouraged the transport of nutrient ions towards roots and their uptake (Narayanamoorthy *et al.,* 2018). At low irrigation frequencies in flood irrigation, water stress occurred and the amount of stored water in the root zone was less than the rate at which the plants take up water (Amarasinghe and Smakhtin, 2014). Improved uptake of nutrients due to use of organic manures either alone or in combination with chemical fertilizers could be attributed to the continuous sustained supply of nutrients over the period of time due to greater activities of microorganisms leading to decomposition and mineralization of organic nutrients. This could also be due to the beneficial impact of vermicompost and/or FYM containing nutrients and vital plant promoting substances in vermicompost (Saranraj and Stella, 2012). Organic manure resulted in higher nutrient content compared to NPK fertilizers due to availability of essential nutrient, especially N and organic matter that are pivotal for plant growth, ultimately leading to higher grain yields (Reza *et al.,* 2016).

CONCLUSION

Drip irrigation and use of integrated nutrient management, alone or together, have the potential to enhance growth parameters, nutrient uptake and production. The outcomes from the study strengthens the hypothesis that the drip irrigation and integrated nutrient management practice (RDF + FYM @2.5 t/ha + vermicompost @1t/ha; T_3) can be handy to harness higher production in vegetable pea economizing the water.

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DECLARATION

The authors declared that they do not have any conflict of interest.

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