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# Water use efficiency and water production function of Pea cultivars

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**Abstract**
Field experiment was conducted during *Rabi* season of 2017-18 in randomized block design with three pea cultivars under varying environments with two irrigation levels. Water use efficiency of pea was calculated for both pod and grain yield and was found higher for $V_2$ followed by $V_1$ and $V_3$. Similar trend was observed both for dates of sowing and irrigation levels but higher values were observed for first date of sowing at first irrigation level. A positive and linear relationship was observed between water use and leaf area index ($R^2$ = 84.2), dry matter ($R^2$ = 83.8), pod yield ($R^2$ = 76.8) and grain yield ($R^2$ = 68.5). It is recommended that sowing of pea may be done on or before 1st December for higher yield and PB-89 variety for *Rabi* season at three days interval of irrigation in mid hills of Himachal Pradesh.

**Keywords:** water production, pea cultivars, *Rabi* season

## Introduction
India has made considerable progress in developing irrigation infrastructure which leads to substantial improvement in production of vegetable crops. Despite this development, the productivity of irrigated area has not reached the desired level. This is due to lower water use efficiency of traditional methods of surface irrigation, which is mainly due to higher water conveyance losses, excess or deficit application of irrigation water and deep losses. Pea (*Pisum sativum* L.) is a cool-season, nutritious legume widely cultivated throughout the world. In India, it occupies an area of approximately 530 ('000) ha with an average productivity of 10.08 MT/ha (NHB, 2017). Over years with steady increase in acreage and production, it has occupied the position of leading cash crop especially in the mid hill zone of Himachal Pradesh. The area under pea crop in Himachal Pradesh is around 23.65 ('000) ha with an annual production of 277.20 ('000) MT (DOA, 2017). The economically important pea crop is famous for being sensitive to water stress at different growth stages and their responses to stress vary, depending on species and genotype, climatic and soil conditions and the phenophase at which stress is experienced (Farah *et al*., 1988) [3].
Inadequate soil moisture is usually a limiting factor in ensuring proper germination and early growth. In recent year's trend has been changed from more productivity per unit land to more productivity per unit water, as water is becoming increasingly scarce. It may be possible to maximize water productivity in pea by proper scheduling of irrigation. To enhance crop water productivity, reduction in evapotranspiration through deficit irrigation and selection of most crucial water need stages i.e. growth stages most vulnerable to water stress conditions has already been reported by Jalota *et al.* (2006) [4]. Therefore, in the present study various associations of water use with crop growth and yield parameters were worked out.

## Materials and Methods
Field experiment was conducted during the *Rabi* season of 2017-18 in the experimental farm of the Department of Environmental Science, Dr. YS Parmar University of Horticulture & Forestry Nauni (30º86'N, 77º16'E and 1275 m amsl) with three pea cultivars under different crop growing environments. The climate of the area is sub-tropical to sub-temperate and semi-humid characterized by cold winters and having distinguished four major seasons in the year. The treatments comprised of two dates of sowing *viz*., $D_1$ (1st December) and $D_2$ (15th December) as main plot and three pea varieties (Azad-P1, PB-89 and ESP-111) as subplot were replicated thrice in a randomized block design. The sowing was done manually in rows at 45 x 20 cm spacing with 4-6 cm depth @ two seeds per hill. The excess plants were thinned out/ gap filling was done at 20 days after sowing (DAS) keeping within row and plant distance maintaining uniform plant stand. The gross and net plot size was 3.0x2.0 m and 2.70 x 1.8 m, respectively. Recommended packages of practices for pea crop were followed (Anonymous, 2017) [1]. Potential evapotranspiration (PET) was calculated using Pan evaporation method, soil moisture was recorded from the field experiment and Water use efficiency was calculated using the formula for both pod and grain yield.

***Water Use Efficiency (WUE)***

The water use efficiency is defined as the marketable crop produced per unit of water used in evapotranspiration. It was calculated by using the following formula:

WUE = Y/ET

Where,
WUE = Water use efficiency (kg/mm of water)
Y = Economic yield (kg/ha)
ET = Evapotranspiration

**Results and Discussion**

***PET using pan evaporation method***

Potential evapotranspiration (PET) is a measure of the ability of the atmosphere to remove water from the surface through the processes of evaporation and transpiration. The PET for $V_3$ was highest under $D_2$ (153.04 mm) followed by V2. Likewise, for $V_2$, the PET was highest for $D_2$ (145.59 mm) as against of $D_1$ (139.12 mm). Similarly, for $V_1$, the PET was highest for $D_2$ (141.36 mm) as compared to $D_1$ (135.68 mm) (Table 1). This may be due to the increase in temperature during the second date of sowing.

**Table 1:** Actual and accumulated PET at different phenological stages of pea cultivars under varying environments

| **Varieties** | **Azad P-1** | | **PB-89** | | **ESP-111** | |
|---|---|---|---|---|---|---|
| Crop growth stages | Actual PET (mm) | Accumulated PET (mm) | Actual PET (mm) | Accumulated PET (mm) | Actual PET (mm) | Accumulated PET (mm) |
| 1st December ($D_1$) | | | | | | |
| Emergence | 13.76 | 13.76 | 13.76 | 13.76 | 15.20 | 15.20 |
| First Node | 14.80 | 28.56 | 16.00 | 29.76 | 15.76 | 30.96 |
| Flowering | 58.32 | 86.88 | 58.24 | 88.00 | 60.72 | 91.68 |
| Pod formation | 22.08 | 108.96 | 23.20 | 111.20 | 29.76 | 121.44 |
| Maturity | 26.72 | 135.68 | 27.92 | 139.12 | 30.56 | 152.00 |
| 15th December ($D_2$) | | | | | | |
| Emergence | 15.76 | 15.76 | 14.56 | 14.56 | 16.88 | 16.88 |
| First Node | 12.32 | 28.08 | 13.76 | 28.32 | 13.20 | 30.08 |
| Flowering | 58.48 | 86.56 | 58.60 | 86.92 | 60.32 | 90.40 |
| Pod formation | 29.28 | 115.84 | 28.79 | 115.71 | 30.08 | 120.48 |
| Maturity | 25.52 | 141.36 | 29.88 | 145.59 | 32.56 | 153.04 |

**Table 2:** Water use efficiency (kg/ha/mm) of pod and grain yield of pea under different treatments

| **Treatments** | **Pod yield (kg/ha)** | **Grain yield (kg/ha)** | **Water Use (mm)** | **WUE (Pod yield)** | **WUE (Grain yield)** |
|---|---|---|---|---|---|
| $V_1D_1I_1$ | 13069.33 | 6986.56 | 152.40 | 85.76 | 45.84 |
| $V_1D_1I_2$ | 13271.22 | 7221.61 | 154.70 | 85.79 | 46.68 |
| $V_1D_2I_1$ | 12768.00 | 6981.45 | 157.00 | 81.32 | 44.47 |
| $V_1D_2I_2$ | 10954.27 | 6423.90 | 155.90 | 70.26 | 41.21 |
| $V_2D_1I_1$ | 13814.13 | 7409.59 | 152.80 | 90.41 | 48.49 |
| $V_2D_1I_2$ | 13625.00 | 7405.50 | 154.75 | 88.05 | 47.85 |
| $V_2D_2I_1$ | 12044.67 | 7283.64 | 156.70 | 76.86 | 46.48 |
| $V_2D_2I_2$ | 11949.78 | 6676.43 | 150.60 | 79.35 | 44.33 |
| $V_3D_1I_1$ | 13637.45 | 7006.23 | 171.00 | 79.75 | 40.97 |
| $V_3D_1I_2$ | 11158.40 | 4531.26 | 170.60 | 65.41 | 26.56 |
| $V_3D_2I_1$ | 12251.15 | 4697.62 | 170.20 | 71.98 | 27.6 |
| $V_3D_2I_2$ | 10257.03 | 4389.46 | 172.30 | 59.53 | 25.48 |

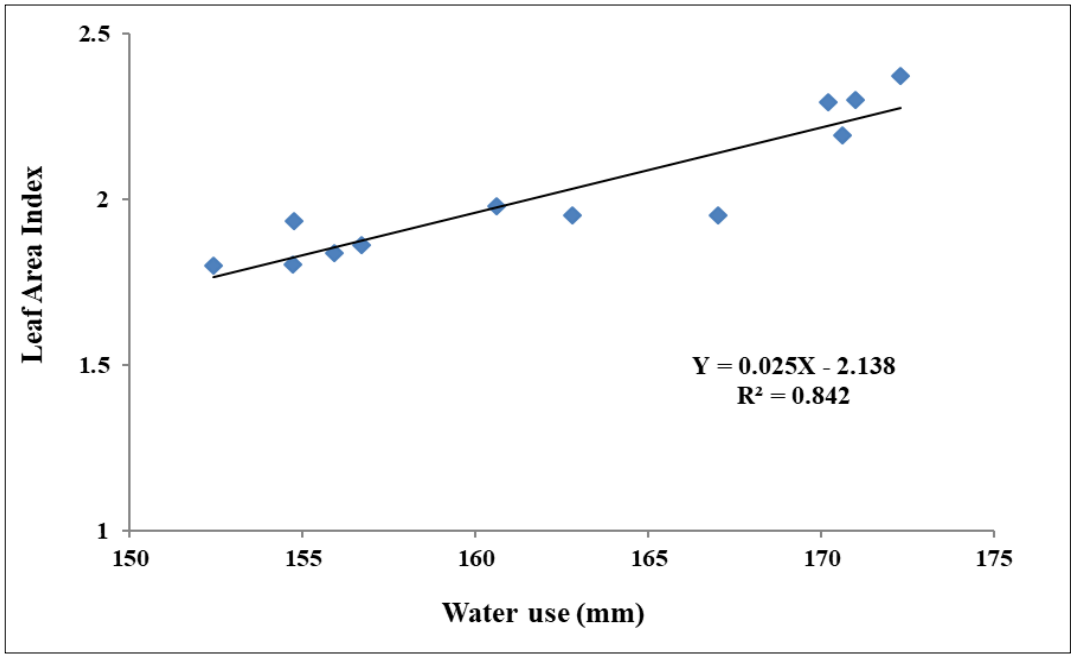


**Fig 1:** Relation of Leaf Area Index with water use in pea cultivars

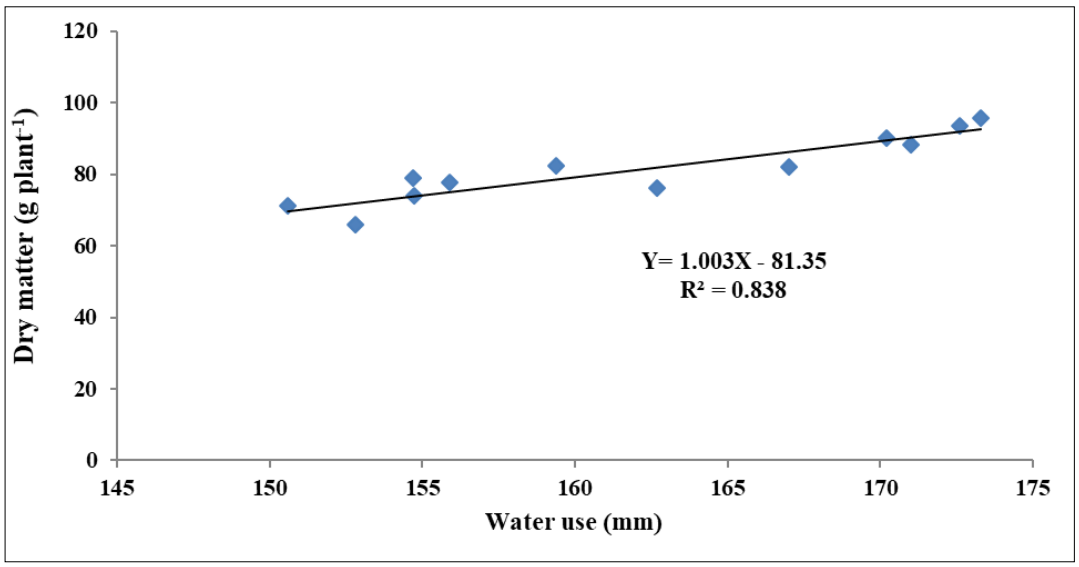


**Fig 2:** Relation of dry matter with water use in pea cultivars

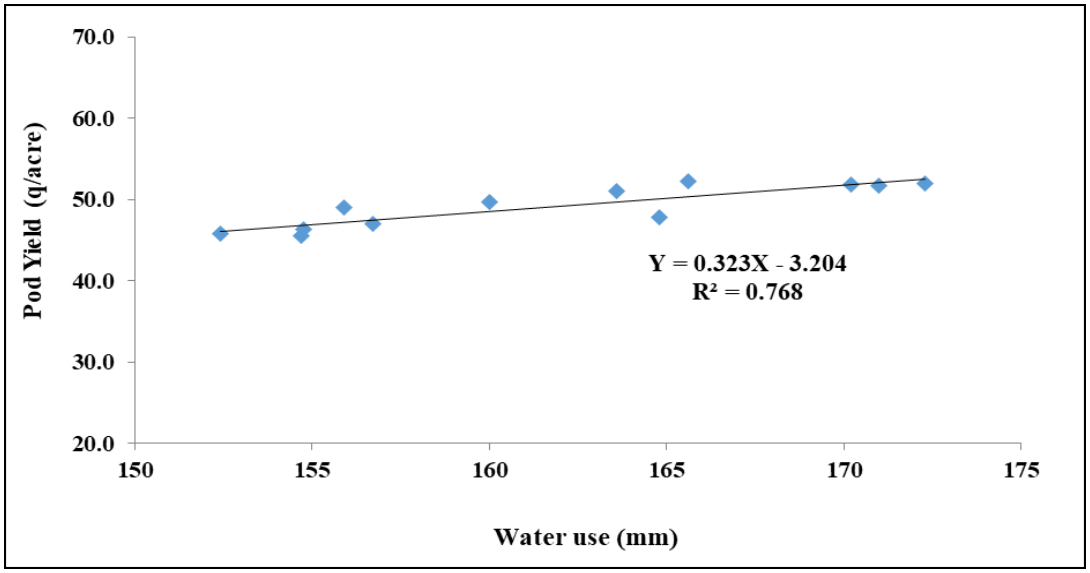


**Fig 3:** Relation of pod yield with water use in pea cultivars

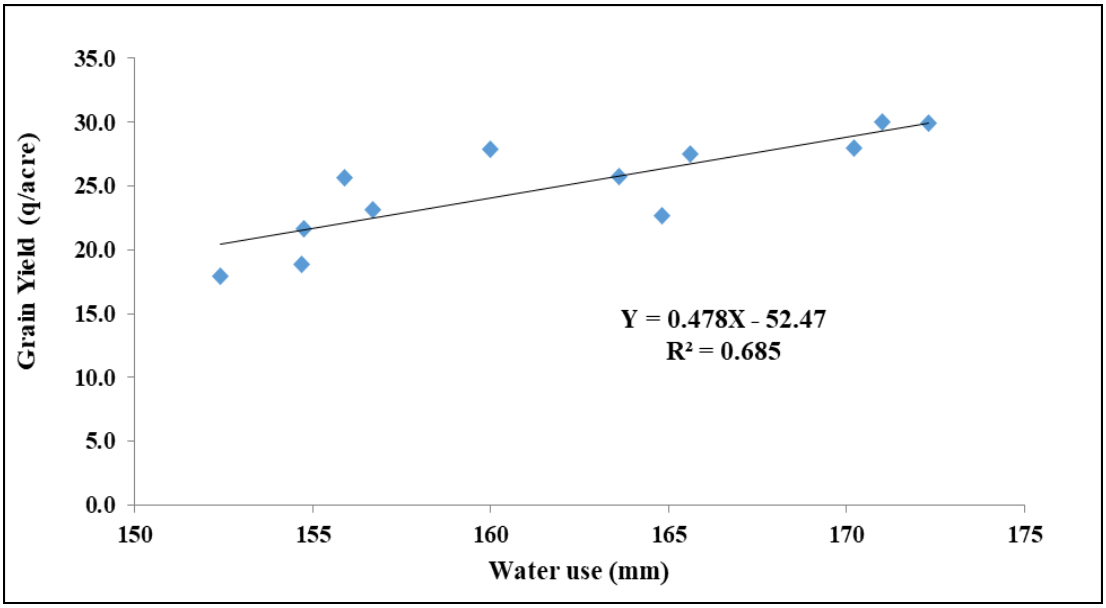


**Fig 4:** Relation of grain yield with water use in pea cultivars

**Water use efficiency**

Water use efficiency of pea was calculated for both pod and grain yield by taking the seasonal consumptive use of water for all the treatments taken is presented in Table 2. Average water use efficiency with respect to pod yield as well as grain yield was found higher for $V_2$ followed by $V_1$ and $V_3$. Water use efficiency of pea was found higher in first date of sowing ($D_1$) as compared to $D_2$. Xiao *et al*. (2009) [7] revealed that with the increase in temperature, water use efficiency decreased. Among the irrigation levels, $I_1$ recorded relatively higher water use efficiency value followed by $I_2$. Water use Efficiency was found higher in $V_2D_1I_1$ due to increased in both pod and grain yield.

Water use efficiency of pea under different sowing dates was observed higher in $D_1$ for both pod and grain yield (481.62 and 253.55 kg/ha/mm) as compared to $D_2$ (452.85 and 232.4 kg/ha/mm), respectively (Fig. 2). Similarly, water use efficiency was also observed higher in PB-89 for pod 334.67 and grain 187.15 kg/ha/mm followed by Azad P-1 (323.13 and 178.2 kg/ha/mm) and ESP-111 (276.67 and 120.53 kg/ha/mm), respectively (Fig. 3).

***Crop water production functions***

**Water use and Leaf area index**

The positive and linear relationship was observed between water use and maximum leaf area index in pea crop under different treatments (Fig. 4). The 84.2 per cent variation in leaf area index was explained by water use by the crop under various treatments and vice-versa.

**Water use and dry matter**

The positive and linear relationship was observed between water use and dry matter accumulation in pea crop under different treatments (Fig. 5). The relation explained 83.8 per cent variation in dry matter accumulation with water consumption by the crop under different sowing time, cultivars and various irrigation levels.

**Water use and pod yield**

A linear and positive relationship was obtained between pod yield and water use by the crop (Fig.6). The linear regression equation explained 76.8 per cent variation in pod yield with water use under different dates of sowing, cultivars and various irrigation levels.

**Water use and grain yield**

A linear and positive relationship was observed between water use and grain yield in pea crop under different treatments (Fig. 7). The regression equation explained 68.5 per cent variation in grain yield with water consumption by the crop under different sowing time, cultivars and various irrigation levels.

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