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Response of cowpea (*Vigna unguiculata* (L). WALP) to varying water table conditions in *tarai* condition of Uttarakhand

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Abstract
A field experiment was conducted during *summer* season of 2016 at N. E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar, Uttarakhand, India. To study the effect of various irrigation schedules, water table depths, irrigation methods and their interaction on cowpea (*Vigna unguiculata*) c.v. Pant Lobia-1. The results revealed that scheduling of irrigation to Cowpea crop under conditions of medium water table (60±1.5 cm) based on CPE 100 mm using sprinkler method of irrigation is most favorable technique for better yield and maximum WUE of Cowpea in *tarai* conditions of Uttarakhand.

Keywords: Irrigation schedules, sprinkler, WUE (Water Use Efficiency), CPE (Cumulative Pan Evaporation), water table

Introduction
Irrigated agriculture is essential to feed the ever growing population in the world. Water resource is at the heart of sustainable development. Agriculture sector draws a major portion of total water supply in India. It is used to assist in the growing of agricultural crops, maintenance of landscapes, and re-vegetation of disturbed soils in dry areas. The demand for water in other sector like industry, power, domestic consumption etc., is also increasing. The main cause of this increase are growing population and rising food demand. In an agrarian economy like India, the importance of water for agricultural productivity hardly needs any emphasis. India faces the daunting task of increasing its food production in the next two decades, and reaching towards the goal of sustainable agriculture requires a crucial role of water (Kumar 1998). Hence to meet the relentless increase in demand for water for various purposes and to get maximum benefits, it is necessary to make water management holistic. Every drop of water should be used judiciously and economically to realize maximum production per unit of water used.

The modern methods like localized irrigation (Drip and Sprinkler) are emerged as efficient enough over traditional surface irrigation method. In surface irrigation systems, water moves over and across the land by simple gravity flow in order to wet it and to infiltrate into the soil. It is often called flood irrigation. Historically, this has been the most common method of irrigating agricultural crops. Sprinkler irrigation is a method of applying irrigation water which is similar to rainfall. Water is distributed by overhead high-pressure sprinklers or guns by pumping. It is then sprayed into the air and irrigated entire soil surface through spray heads so that it breaks up into small water drops which fall to the ground. A system utilizing sprinklers, sprays, or guns mounted overhead on permanently installed risers is often referred to as a *solid-set* irrigation system. Higher pressure sprinklers that rotate are called *rotors* and are driven by a ball drive, gear drive, or impact mechanism.

Transpiration is necessary evil. Because water transpired through leaves comes from the roots, plants with deep roots can more constantly transpire water. Factors that affect evapotranspiration include the plant's growth stage, percentage of soil cover, solar radiation, humidity, temperature, and wind. Evaporation and transpiration occur simultaneously. Apart from the water availability in the topsoil, the evaporation from a cropped soil is also determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases as the growing period increases as the crop develops and the crop canopy shades more and more of the ground area.

When the crop is small, water is predominately lost by soil evaporation, but when the crop is well developed and completely covers the soil, transpiration becomes the main process. At the time of sowing nearly 100% of ET comes from evaporation, while at full crop cover more than 90% of ET comes from transpiration. The rate of evapotranspiration is normally expressed in millimetres (mm) per unit time. The rate expresses the quantity of water lost from a cropped surface in units of water depth. The time unit may be an hour, day, decade, month or even an entire growing period or year and generally expressed in terms of mm day^{-1} or m^3 ha^{-1} day^{-1}.

Lysimeter is a measuring device which measures the amount of actual evapotranspiration which is released by plants and soil. By recording the amount of precipitation and the amount lost through the soil, water lost through evapotranspiration can be calculated.

Pulses are the basic ingredient in the diet of most of the Indian population, as they provide vegetarian protein component of high biological value when supplemented with cereals. Cowpea (*Vigna unguiculata* (L). is a higher drought-tolerant crop than many other crops. It can be grown under rainfall ranging from 400 to 700 mm per annum. Cowpeas are also having a great tolerance to water logging. It is more tolerant to infertile and acid soils than many other crops. Cowpea had emerged as a multipurpose crop, because can be grown for its mature beans, which serve as pulses, or grown for its immature pods and leaves which are utilized as vegetable. The stem or haulm serves for livestock as fodder. Feeding value of forage cowpea is high and comparable to Lucerne, concentrate feed for cattle and excellent forage. Used as green manure, cover crop and catch crops. Cowpea is a very important legume in regions where water stress is the major constraint for its production (Santos 2000) [4]. The overview of the crop water demand and irrigation scheduling based upon IW/CPE ratio for optimizing irrigation water use establishes the need for generating information on crop evapotranspiration by direct measurements, and of calibrating the crop climate based procedures to estimates actual evapotranspiration of crops at daily and weekly intervals. There is a need for developing information on the effect of moisture deficit on crop yield. This combined information can be used to study response of grain cowpea under varying water table conditions at farm level.

Materials and Methods

Experimental Site

Experiment was conducted during summer season of 2016 consisted of batteries of 36 non-weighing type lysimeters at N. E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar, Uttarakhand, India. Pantnagar, located at 29^0 N latitude, 79°30' E longitude and at an altitude of 243.8 m above the mean sea level. It lies in *tarai* belt of Uttarakhand at the foot hills of Shivalik range of Himalayas and falls in humid sub-tropical climatic zone.

Soil and weather of crop duration

The soil filled in lysimeters has been classified as Beni silty clay loam (Deshpande *et al.* 1971) [1] having pH 7.16 and EC 0.31 dS m^{-1}. The soil was medium in Organic carbon (0.67%), low in Nitrogen (227.6 kg N ha^{-1}), low in phosphorus (16.4 kg P_2O_5 ha^{-1}) and medium in potassium (185.7 kg K_2O ha^{-1}).The standard meteorological week data indicated that maximum temperature ranged from 29.2 ^{0}C to 39.0 ^{0}C and minimum temperature ranged from 12.1 °C to 26.6 °C during crop growth.

Experimental Details

The experiment was conducted during summer season of 2016 with cowpea crop (variety Pant Lobia-1) under various irrigation schedules in 36 non-weighing lysimeters. The experiment consisted of 18 treatment combinations (Table-1) having three factors. The first factor is three water table depths (30$\pm$1.5, 60$\pm$1.5 and 90$\pm$1.5 cm), second is three irrigation schedules i.e. irrigation at 100 mm CPE, 150 mm CPE and 200 mm CPE and third factor is two irrigation methods viz. flood and sprinkler. All 18 treatment combinations were laid out in Factorial Randomized Block Design. Each treatment was replicated twice and all 36 lysimeters were used for this study. The dimension of Lysimeter tank was 1.8 m x 1.5 m x 1.5 m. Depth of Irrigation was 3 cm with flood method and 2 cm with sprinkler method. The cowpea cv. Pant Lobia-1 was raised by direct sowing using seed rate of 30 Kg ha^{-1}. Row to row spacing of Cowpea was 30 cm and Plant to plant spacing after thinning was 10 cm. 5 rows of plants were kept between each lysimeter tank. After seed germination, 90 plants per lysimeter were maintained after thinning, same plant population was also maintained in area surrounding the lysimeters. The recommended doses of fertilizer @ 25 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and 20 kg K_2O ha^{-1} was used.

Design and construction of lysimeters

Lysimeters are constructed in 6 batches, each batch contains 6 in number and arranged in two rows each consists of 3. The distance between lysimeters within batch is 1.5 m. Each batch of lysimeters is located 5.25 m away. The run off collection tanks are 5.3 m away from every batch of lysimeters. The lysimeters are rectangular in shape and the dimension of the inner wall of tanks is 1.8 m long, 1.5 m wide and 1.5 m deep. The tanks are made of 10 cm thick wall of R.C.C. in the ratio of 1: 2: 4 (cement: sand: shingle) with reinforcement of iron-rods of 1.2 cm diameter. The water-proofing compound (Ecoproof) was added at the rate of 1 kg per bag of cement and tanks were plastered from inside as well as outside with mixture in the ratio 1:3 (cement: sand) and 1kg of water proofing compound per bag of cement. Three Galvanized iron pipes of 2 cm diameter which are resistant proof to heat and moisture are connected. One at the bottom, second at 6 cm above the bottom, and third at 5 cm below from the top of the tanks which are called as drainage pipe, water table maintaining pipe and run off pipe respectively.

The drainage system consists of filter network at the bottom of tank, drainage pipe and drainage collection tanks. The drainage pipe runs to drainage collection tanks at the end a drain cock is fitted to regulate the required drainage rate. The top surface of the drainage collection tanks is 3 cm below the bottom of lysimeter tanks to facilitate the flow of water. The dimension of drainage tanks is 0.6 m by 0.6 m by 0.6 m. The calibrated carboys were placed in every tank to measure the value of effluent. To prevent it from rain and evaporation Plastic covers were placed.

The graded filter network is placed at the bottom of lysimeter tanks. It consists of wire net glass wool, gravel and sand. A wire net of 2 mm size is placed on neck drainage and water table maintenance pipes followed by glass wool. Ten cm thick layer of gravel (2 cm size) is placed in all lysimeter tanks followed by 5 cm layer of sand (2 mm).

Water table maintenance system
This system consists of water table maintenance tanks and water table maintenance pipes. The tanks are constructed by R.C.C. at different heights for maintenance of different water tables in lysimeter tanks. The dimension of inner wall of tanks is 1 m by 1 m in area and 0.5 m deep having a window of 0.6 m by 0.3 m size, with sloppy roof. The thickness of wall is 10 cm and the same constructions specification was followed as in lysimeter tanks. The water table maintenance pipes are connected at the bottom of the tanks.

Run-off collection system
It consists of run-off collection tanks, run-off pipes and drainage cocks. The run-off pipes from lysimeter tanks are connected with run-off collection tanks. The dimension of inner wall of tanks is 0.8 m × 0.8 m x 0.8 m with sloppy roof and 10 cm thick wall. They are constructed by R.C.C. work as described in lysimeter tanks.

Filling up of lysimeters
The lower soil horizon 81 to 120 cm was placed in lysimeters and irrigated up to 2 cm of submergence. After 48 hours next horizon 51 to 80 cm was placed and irrigated up to 2 cm of submergence, which was again left for 48 hours. Likewise 21 to 50 cm and 0 to 20 cm horizons were filled up. Five wetting and drying cycles were imposed to have better settlement of soil. After four months, lysimeters were used for experimental purpose.

Result and Discussion
The results and their statistical analysis to depicting the effect of various irrigation schedules, water table depths, irrigation methods and their interaction on cowpea have been presented and discussed in the light of the research work quoted by earlier workers. The readings are being presented under the following heads.

Evapotranspiration, total water use, yield and water use efficiency
Cowpea as being leguminous crop it`s having less water demand as compare to cereals and other high water requirement crop. Evapotranspiration, water applied, total water use, seed yield and water use efficiency of cowpea as measured in lysimeters under various irrigation schedules and methods of irrigation under varying water table conditions during *summer* season of 2016 are presented in Table 2.
Data showed that ET was low during earlier growth stage of the Cowpea crop and increased with increase in growth stage of the crop till flowering and pod formation stage and declined thereafter. ET also increased with increase in moisture supply through irrigations as well as under shallow (30±1.5 cm) water table condition. The maximum value of evapotranspiration (627.25 mm) was found in irrigation schedule based on CPE 100 mm receiving 6 irrigations using flood method of irrigation in 30±1.5 cm water table conditions and ET was minimum (318.31 mm) in irrigation schedule based at CPE 200 mm receiving three irrigation through sprinkler method under 90±1.5 cm water table conditions. Among all three water table depths highest value of ET was obtained under 30±1.5 cm water table depth compared with 60±1.5 and 90±1.5 cm water table conditions. Also highest value ET (627.25 mm) was found at CPE 100 mm by flood method under 30±1.5 cm water table depth. At CPE 100 mm when irrigated by sprinkler method then also highest ET was found (567.18 mm) at 30±1.5 cm water table depth. At CPE 150 mm the highest value of ET (507.55 mm) was found when irrigated by flood and 530.68 mm when irrigated by sprinkler method at 30±1.5 cm water table depths. When irrigations were given at CPE 200 mm then also highest ET (567.65 mm) was found at 30±1.5 cm water table depth, when irrigated by flood and was 530.02 mm when irrigated by sprinkler method. Results clearly indicated that ET values were found to be more when irrigation was given more frequently (at CPE 100 mm). The above findings of more ET at shallow water table condition and at frequent irrigation are due to more availability of water for transpiration.

Total Water Use (mm)
The number of irrigations required at 100 mm, 150 mm and 200 mm CPE was 6, 4 and 3, respectively during the entire *summer* season under three water table conditions. Maximum total water use (1134.75 mm) was found under 30±1.5 cm water table depth under CPE 100 mm irrigation treatment and the flood method of irrigation among all irrigation treatments (Table-3). However, minimum total water use under 90±1.5 cm water table depths was 705.81 mm under CPE 200 mm and sprinkler method of irrigation treatment among all irrigation treatments.

Effect on Yield
The data pertaining yield of the Cowpea crop observed in each lysimeter and converted to kg ha^{-1} is presented in Table-1. Results clearly indicated that the grain yield of Cowpea was affected by water table depths, irrigation schedules and methods of irrigation. The maximum grain yield of 1017.57 kg ha^{-1} was obtained in lysimeters associated with 60±1.5 cm water table depth where 6 irrigations were given based on CPE 100 mm by sprinkler method of irrigation fallowed by 940.91 kg/ha, receiving same number of irrigations and same irrigation method under 90±1.5 cm water table condition. Most favourable water table condition for higher yield is 60±1.5 cm water table depth. Among all the three irrigation schedules, irrigation at CPE 100 mm produced highest yield 933.77 kg/ha. Sprinkler method of irrigation produced 22.5 percent more grain yield than flood method of irrigation. The higher yield with more number of irrigations might be due to appropriate availability of moisture and better availability of nutrients brought about by increase in water availability. In all the water table depth and irrigation schedules sprinkler method of irrigation mostly produced the highest yield. Thus sprinkler method was found to be superior over flood method. These results are similar with the findings of Abomera 2004 and Chowdhury *et al.* 2014 [3]. They also reported higher seed yield with higher irrigation frequency.
The better performance of yield and yield attributes in medium water table depths, frequent irrigation as well as in conditions under sprinkler method of irrigation was possibly due to favourable micro-climatic conditions, availability of timely and adequate moisture for plant growth and keeping soil structure loose and fragile. Over all application of irrigation favoured the cell division, cell elongation and turgidity maintenance of plants which in turns led to better plant growth, increased photo synthetically active area and assimilation of more photosynthates. Since the increased availability of moisture and nutrients availability led to increased growth and further transfer of photosynthates to reproductive organ thereby influenced to increase the yield. But as cowpea is a pulse crop and it is known that more watering enhances the excess vegetative growth of pulses. The photosynthates more diverted towards vegetative parts

than reproductive parts and thus flowering and fruiting gets negatively affected. Due to less availability of photosynthates as well as duration for flowering and fruiting, yield decreases.

Water use efficiency (WUE)

The effect of different factors clearly indicated that WUE was maximum (1.20 kg/ha-mm) under 60±1.5 cm water table depth scheduled by sprinkler method on CPE 100 mm. However, lowest value of WUE was found to be 0.70 kg/ha-mm under 30±1.5 cm water table conditions where six irrigations were given based on CPE100 mm following flood method of irrigation.

Table 1: Irrigation treatments details with their symbols

Symbol	Irrigation Treatments
T_1	Irrigation at IW : CPE 0.3,CPE 100 mm (flood method)
T_2	Irrigation at IW:CPE 0.2, CPE 100 mm (sprinkler method)
T_3	Irrigation at IW : CPE 0.2, CPE 150 mm (flood method)
T_4	Irrigation at IW : CPE 0.13, CPE 150 mm (sprinkler method)
T_5	Irrigation at IW : CPE 0.15, CPE 200 mm (flood method)
T_6	Irrigation at IW : CPE 0.10, CPE 200 mm (sprinkler method)

Table 2: Evapotranspiration (ET), total water use, grain yield & water use efficiency (WUE) of cowpea during summer season of 2016 in lysimeters

Irrigation treatments & water table depth	Evapotranspiration (mm)	Total water applied (mm)*	Total water use (mm)	Grain yield (Kg/ha)	Water use efficiency (kg/ha-mm)
CPE 100 mm, Flood					
30±1.5 cm	627.25	507.5	1134.75	796.77	0.70
60±1.5 cm	546.87	507.5	1054.37	11.69	0.77
90±1.5 cm	499.69	507.5	1007.19	803.67	0.79
CPE 100 mm, Sprinkler					
30±1.5 cm	567.18	447.5	1014.68	898.06	0.88
60±1.5 cm	399.02	447.5	846.52	1017.57	1.20
90±1.5 cm	398.56	447.5	846.06	940.91	1.11
CPE 150 mm, Flood					
30±1.5 cm	507.55	447.5	955.05	791.66	0.83
60±1.5 cm	385.98	447.5	833.48	788.45	0.95
90±1.5 cm	323.26	447.5	770.76	727.43	0.94
CPE 150 mm, Sprinkler					
30±1.5 cm	530.68	407.5	938.18	804.23	0.86
60±1.5 cm	445.99	407.5	853.49	807.5	0.95
90±1.5 cm	375.53	407.5	783.03	791.66	1.01
CPE 200 mm, Flood					
30±1.5 cm	567.65	417.5	985.15	729.67	0.74
60±1.5 cm	437.90	417.5	855.40	751.02	0.88
90±1.5 cm	348.70	417.5	766.20	691.81	0.90
CPE 200 mm, Sprinkler					
30±1.5 cm	530.02	387.5	917.52	707.77	0.77
60±1.5 cm	394.38	387.5	781.88	793.67	1.01
90±1.5 cm	318.31	387.5	705.81	753.69	1.06

*(Irrigation + Rainfall)

Table 3: Standard meteorological week (SMW) average of evapotranspiration (cm) influenced by various irrigation schedules with sprinkler (S) and flood (F) methods of irrigation under 30, 60 and 90 cm water table conditions in non-weighing lysimeters for Cowpea cv. Pant lobia-1 during summer season 2016

SMW No.	Duration of Cowpea crop	CPE=100 mm (S)			CPE= 150 mm (S)			CPE=200 mm (S)			CPE=100 mm (F)			CPE= 150mm (F)			CPE= 200 mm (F)		
		30	60	90	30	60	90	30	60	90	30	60	90	30	60	90	30	60	90
11	12/03/2016-18/03/2016	..58	1.36	1.58	2.32	2.93	1.38	2.30	1.06	0.92	2.78	2.46	1.87	2.19	1.85	1.47	1.77	1.44	1.61
12	19/03/2016-25/03/2016	3.14	2.07	1.66	2.68	1.99	1.70	2.38	1.23	1.22	3.03	3.46	2.36	2.47	2.33	1.88	2.90	2.32	2.44
13	26/03/2016-01/04/2016	2.96	2.17	2.34	3.06	1.52	1.77	2.96	2.47	1.79	2.81	3.39	2.53	3.42	2.49	1.79	3.38	2.29	2.85
14	02/04/2016-08/04/2016	3.19	2.36	3.33	3.11	1.56	1.49	3.18	2.38	1.48	3.22	3.63	2.52	3.59	2.38	1.83	3.99	1.93	2.20
15	09/04/2016-15/04/2016	4.05	2.62	3.60	4.19	2.37	1.51	3.61	2.10	1.50	4.42	3.61	2.73	3.29	2.61	1.55	3.69	2.49	1.43
16	16/04/2016-22/04/2016	4.32	2.68	3.09	3.83	3.39	2.27	3.93	2.40	1.99	4.93	3.67	3.24	3.79	3.07	1.80	3.70	2.60	2.08
17	23/04/2016-29/04/2016	5.66	4.39	4.01	5.65	3.68	3.14	6.22	4.57	2.68	5.79	4.97	4.13	5.51	3.31	2.41	6.05	4.39	2.63
18	30/05/2016-06/05/2016	4.47	3.87	3.01	4.10	4.63	3.80	4.06	2.93	2.61	5.53	4.35	4.60	4.63	3.04	2.71	4.57	4.25	3.14
19	07/05/2016-13/05/2016	4.10	2.62	2.93	3.94	3.48	2.92	3.92	2.24	2.08	5.15	3.27	4.52	3.93	2.86	2.56	4.40	3.06	2.17
20	14/05/2016-20/05/2016	5.56	4.01	3.47	5.53	5.18	5.33	6.37	4.20	3.66	5.40	3.77	5.30	4.73	3.85	4.10	6.45	5.85	4.02
21	21/05/2016-27/05/2016	3.36	3.22	2.87	3.22	4.02	3.92	2.79	3.85	3.55	4.50	3.19	4.66	3.13	3.46	2.96	4.13	4.44	3.35
22	28/05/2016-03/06/2016	5.04	3.29	3.41	4.29	3.73	3.11	4.11	3.73	3.26	5.75	5.39	4.56	3.93	2.92	3.12	3.85	2.70	2.63
23	04/06/2016-10/06/2016	4.43	2.69	2.48	3.94	3.16	2.80	3.80	3.45	2.75	5.27	5.22	3.85	3.16	2.35	2.13	4.31	3.19	2.28
24	11/06/2016-17/06/2016	3.88	2.52	2.08	3.21	2.94	2.42	3.37	2.84	2.35	4.14	4.31	3.11	2.99	2.10	2.01	3.58	2.85	2.03
Total (ET) in cm		56.72	39.90	39.86	53.07	44.60	37.55	53.00	39.44	31.83	62.72	54.69	49.97	50.75	38.60	32.33	56.77	43.79	34.87

Conclusions

Thus it can be concluded from this study that scheduling of irrigation to Cowpea crop under conditions of medium water table (60±1.5 cm) based on CPE 100 mm using sprinkler method of irrigation is most favorable technique for better yield and maximum WUE of Cowpea c.v. Pant Lobia-1 in *tarai* conditions of Uttarakhand. Cowpea crop can be taken as an additional crop during summer season for economic benefits.

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