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Effect of Low Sprinkling Distribution Uniformity on Yield of Wheat using Set Sprinklers

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ABSTRACT

Uniformity of soil moisture under sprinkler irrigation is important for plant quality; however, sprinkler systems are typically gauged by the uniformity of application above the crop canopy as stated by Dukes *et al.* (2006). The uniformity with which an irrigation system applies water has an effect on the efficiency of the system. The uniformity of an irrigation system needs to be high to ensure that the majority of the crop receives an adequate amount of water. This study was carried out to evaluate the effect of Low sprinkling distribution uniformity on the yield of Wheat. This study revealed that low distribution uniformity will result in low yield. It also reveals that to maximize the yield of wheat the depth of irrigation should be doubled when irrigating using sprinkler irrigation on daily basis.

Highlight

- Response of crop yield to moisture distribution uniformity of sprinklers.

Keywords : Sprinkler uniformity, wheat yield

One of the main challenges of world is water and food security. To meet the present and future demand of food grain, optimum utilization of water is necessary. The increasing food demand and decreasing water allocation suggest that the agricultural sector has to increase agricultural water productivity for producing more food with less water (Cai and Sharma 2010). Extensive development of irrigation facilities in India has contributed substantially to the increased food production. However, unscientific and inefficient use of water in several areas, led to undesirable effects threatening long term sustainability of agricultural production. Water is a prime natural indispensable, finite and vulnerable resource. However, the need for portable water is escalating because of rapid industrialization and increasing population especially in the region where water is scarce. With increasing demand on water resources, irrigation efficiency has become an important issue for the farmers and the water managers' worldwide. Sprinkler irrigation represents the broad class of pressurized irrigation methods. The usual goal of sprinkling is uniform watering for entire field. Application of water to the soil through sprinklers is based on the principle of no runoff. Sprinkler irrigation is becoming increasingly popular in India in regions of water scarcity where available water is insufficient to irrigate the command area by surface irrigation.

In such regions, by adopting suitable cropping patterns consisting of crops having high water requirements like wheat and those having low water requirements like mustard and gram, much higher area can be brought under irrigation and farm income increased substantially by adopting sprinkler irrigation. Sprinklers are also being increasingly used for irrigating a high valued plantation crops like tea, coffee, cardamom and orchards. Irrigation systems evaluation is done based on irrigation efficiency indices such as uniformity coefficient, distribution uniformity and application efficiency. Determination of irrigation efficiency indices can help decision makers, engineers, researchers and water users in planning, designing and operating strategies of irrigation system. Literature states that, various studies have been carried out on water distribution and irrigation system effects on crops yield. To understand the crop yield under sprinkler irrigation it is necessary to understand how the crop will respond under very low distribution uniformity obtained using single overhead sprinkler. The main objective to irrigate using sprinkler irrigation is to obtain uniform depth of irrigation. This study was carried out to understand the actual response of water to yield of wheat crop.

MATERIALS AND METHODS

Field experiment was conducted at Irrigation Research Station of Allahabad Agricultural Institute – Deemed University, Allahabad, U.P. India. (25°, 27° N, 81° 44° E 98 m above mean sea level) during the winter crop growing period (December – April) in order to examine the effect of low distribution uniformity of set sprinkler irrigation on crop yield of Wheat. The Allahabad district is located in the north part of India and south-east part of Uttar Pradesh (U.P.) state. It has an area of 5246 sq km. The Allahabad district receives an annual rainfall of 600 to 800mm. Ganga and Yamuna, which originates respectively, from Himalaya Glacier, are the two major rivers of the Allahabad District. The climate in this part of country has been classified as semi-arid with cold winter and hot summer. The soil of the experimental field was fertile clay loam (35.5% sand, 25.8% silt and 38.6% clay) with average bulk density of 1.31 g/cm^3. The plant available soil moisture was 136 mm/m and 0.28. The experiment was conducted in five replications each for Wheat. The area of each experimental plot was 100m^2 (10m × 10m). Wheat (PBW 343) was sown at a row to row spacing of 20 cm. Before sowing the experimental field was properly ploughed, well pulverized and leveled to provide good tilth. Crop was irrigated daily according to the daily crop water requirement using sprinklers. The irrigation system was designed and installed to meet the objectives of the proposed research work. The sprinklers mounted on 1 m high riser were installed at the corner of each plots. The flow rate for the sprinkler used was 0.3 1/s at the pressure of 2.5 kg/cm^2. The irrigation water was directly pumped from the concrete water tank. Screen filter was installed on the main line to minimize sprinkler blockage. Standard cultural practices were adopted during the crop growing seasons.

Crop Water Requirement

The crop water requirement (ET crop) for the crop grown was calculated by the following method:

$$\text{ET crop} = \text{Kc ETp} \tag{1}$$

Where, Kc = crop coefficient, ETp = reference/potential evapotranspiration, mm/day, ET crop = crop water requirement mm/day

The modified penman's model (FAO, 1977) was used to estimate the potential / reference evapotranspiration (ETp). The detail of the model is given as below:

$$\text{ETp} = C\,[\,WRn + (1- W)F(u)\,(ea\text{-}ed)],\ \text{mm/day} \tag{2}$$

Where, ETp = reference/potential evapotranpiration, mm/day, W = temperature related weighting factor, Rn = net radiation in equivalent evaporation mm/day, F (u) = wind related function, (ea – ed) = difference between the saturation vapour pressure at mean air temperature and mean actual vapour pressure of the air, mbar., C = adjustment factor to compensate day and night weather condition.

The components of the modified penman's model were estimated as:

1. Actual vapour pressure, ed was completed by following formula:

$$R.H. = \frac{e_d}{e_a} \times 100 \tag{3}$$

Where, R.H. = Relative humidity, % (obtained from meteorological office), ea = Saturated vapour pressure (obtained from table FAO, 1977)

2. Wind velocity at 2 m height was contorted in respective 5 m height with the help of correction factor and F (u) was calculated by the following formula:

$$F(u) = 0.27\ (1+ U/100) \qquad (4)$$

Where, U = 24 hrs wind speed at 2m height, km/day

3. Temperature related weighing factor W and (1 – W) were obtained from standard Tables for respective air temperature (FAO, 1977)
4. Net radiation (Rn) was calculated with the help of the series of formulae (FAO, 1977)

$$Rn = Rns - Rni \qquad (5)$$

Where, Rn = net radiation in equivalent evaporation, mm/day, Rns = net short wave radiation, mm/day, Rni = net long wave radiation, mm/day, ₹ = (0.25 + 0.5 n/N) Ra, Rns = (1 – α) ₹

Where, n = Actual sunshine hour, N = Maximum sunshine obtained from Table with respect to latitude and time of year, hour (FAO, 1977), Ra = Extra terrestrial radiation obtained by table on the basis of latitude and time of year, mm/day (FAO, 1977), ₹ = Solar radiation in equivalent evaporation, mm/day, α = Reflectivity factor, depends upon crop surface, leaf area index and vegetation, fraction (FAO, 1977)

$$R_{ni} = f(T)\ f(e_d)\ f(n/N)$$

Where, F(T) = function of temperature, obtained Table against known mean air temperature, (FAO, 1977), F (ed) = function of saturated vapour pressure, obtained from table (FAO, 1977), F (n/N) = function of actual sunshine hour to maximum sunshine hour, obtained from table, (FAO, 1977).

Irrigation Requirements

Following field water balance model was employed to complete the net irrigation requirement.

$$L_n = Et_{crop} - (P_e + G_w + W_b) \qquad (6)$$

Where, L_n = net irrigation requirement, Et_{crop} = crop water requirement, P_e = effective rainfall, G_w = Ground water contribution.

W_b = Stored soil water at the beginning of each period

All variables in the above equation are expressed in terms of depth of water (mm)

Leaching requirement for crop grown was estimated by the following equation:

$$LR = \frac{EC_w}{5EC_e - EC_w}$$

Where, EC_w = electrical conductivity of the irrigation water, mm hos /cm, EC_e = electrical conductivity of the soil saturation extraction for a given crop appropriate to the tolerate degree of the yield reduction, mm hos /cm.

Distribution uniformity (DU)

In order to put a numerical value on the uniformity of application for sprinkler irrigation system and the yield of wheat Distribution uniformity DU (Merriam and Keller, 1978) was used. It is computed by:

$$DU = \frac{\text{Average low quarter depth of water received}}{\text{Average depth of water received}} \times 100 \qquad (7)$$

Uniformity Coefficient (UC)

The Christiansen Uniformity Coefficient was calculated using the relation:

$$CU = 100 - 0.63(100 - DU) \qquad (8)$$

RESULTS AND DISCUSSION

Yield response of wheat under low distribution uniformity

The sprinkling droplet distribution pattern obtained by using single leg catch can data as shown in the Fig. 1 explains the variation between the depths of water in the study area. Since in actual field conditions while irrigating wheat this water is not confined in 2m × 2m boundary but the infiltration of the water is three-dimensional. The water when sprayed in the wetted area did not create poundings because special care was taken to check the flow of water from one division to another.

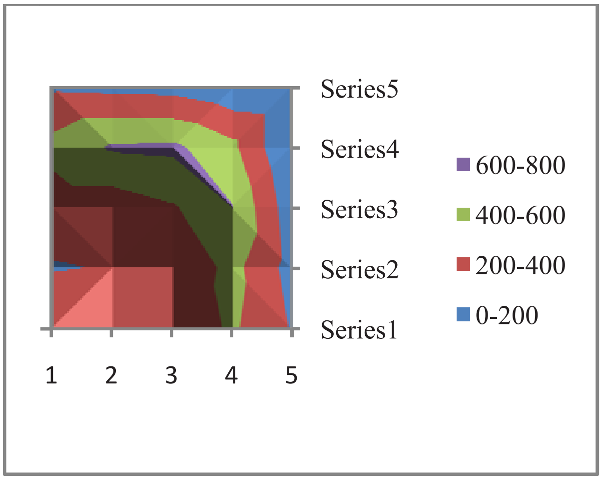

Fig. 1: Sprinkling Distribution Uniformity

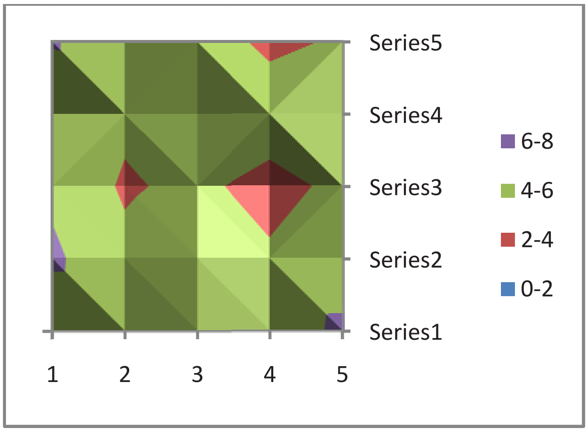

Fig. 2: Wheat Yield Distribution Uniformity

Relationship between moisture profile and yield of wheat

The moisture distribution due to precipitation of water as shown in Fig. 1 is compared with Fig. 2. Fig. 1 has been classified into four groups i.e. 0 mm – 200 mm, 200 mm – 400 mm, 400 mm – 600 mm and 600 mm – 800 mm. From both the figures it was seen that in the case of extreme water deficit the yield range between 3 – 4 t/ha whereas for the range of 200 mm – 400 mm the yield is ranging between 4 – 6 t/ha. This is due to the fact that at the outer wetting front of the wetted area the moisture is moving towards the outer area due to change in gradient. The maximum yield of 4 – 5 t/ha was observed nearer to the sprinkler in spite of that area having 200 mm – 400 mm, 400 mm – 600 mm, 600 mm – 800 mm wetting profile. When we compare this particular distribution with the yield it can be seen in Fig. 2 that the yield is most uniform in this area because of horizontal movement of soil moisture.

The water applied for wheat is shown in table 1. The data in the table has been put in the ascending order. From the table it can be seen that in spite of areas receiving no precipitated sprinkled water some yield is observed. At 0 mm precipitation the yield of wheat is 4.30 t/ha. This is due to the fact that the precipitated water moves horizontally into the soil.

Table 1: Precipitation depth in ascending order and their corresponding yield of wheat

Depth of precipitation, mm	Yield (Wheat), t/ha
642	4.53
623	4.41
605	3.15
472	4.34
472	4.16
454	5.49
435	4.55
378	4.52
340	4.34
283	5.62
283	3.75
246	4.36
246	5.44
208	4.51
208	5.37
189	6.47
189	6.35
170	6.21
151	4.43
132	4.54
132	5.40
95	4.61
38	3.43
0	4.41
0	4.30

The relationship between depth of water and yield is shown in Fig. 4 it can be seen that as the depth of precipitation increases the yield response is parabolic. The maximum yield of 6.47 t/ha was found to be at 189 mm. From table 1 and Fig. 3 it can be observed that in order to get maximum yield of wheat using sprinkler irrigation the mean depth of water should be 189 mm.

Sprinkler	2m	4m	6m	8m	10m
2m	340	246	246	435	189
4m	189	208	208	472	132
6m	283	283	378	605	95
8m	472	623	642	454	0
10m	170	151	132	38	0

Fig. 3: Depth of precipitation during crop growing season (mm)

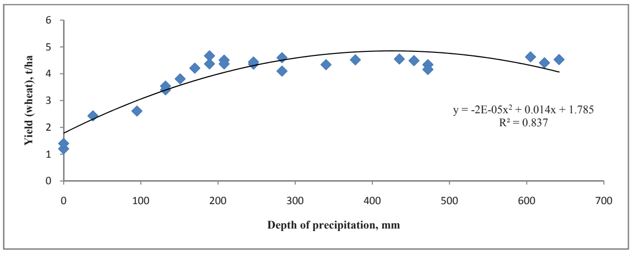

Fig. 4

Since the irrigation was done on daily basis the soil moisture status did not change also no precipitation (rainfall event) occurred during the entire crop-growing period.

CONCLUSION

Distribution uniformity of sprinkled water is a very important factor to be considered while irrigating the field using sprinklers. Single leg catch can data were used and also only a quarter of the wetted area was irrigated to understand how low distribution uniformity is affecting the yield of wheat. The result revealed that the yield varies with the change in depth of irrigated water. The distribution uniformity of the yield of wheat was found to be at 81.59% although irrigation was done using single sprinkler with low distribution uniformity of only 23.66%. Sprinkling Christiansen uniformity coefficient was observed to be 51.90% and Wheat yield uniformity coefficient was 88.40 % respectively. This phenomenon indicates that the water is having increased distribution uniformity in the soil resulting in higher yield distribution uniformity. The maximum and minimum yield of wheat was found to be 6.47 t/ha and 3.15 t/ha at 189 mm and 0 mm respectively. The study reveals that low distribution uniformity will result in low yield. It also reveals that to maximize the yield of wheat the depth of irrigation should be doubled when irrigating using sprinkler irrigation on daily basis. The real concern should be about how evenly the moisture is distributed above the soil i.e. in catch cans. Hence it is strongly recommended that studies should be conducted to understand the soil moisture uniformity and yield.

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