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Irrigation dynamics of laser spray and rain port systems

Y. Pavan Kumar Reddy[1], V.Siva Jyothi[1], B. Sahadeva Reddy[2] and Y. Padma Latha[3]

[1]*ANGRAU-Agricultural College, Mahanandi, AP, 518502-India*
[2]*ANGRAU-Regional Agricultural Research Station, Maruteru, AP, India*
[3]*ANGRAU (Acharya N. G. Ranga Agricultural University), Andhra Pradesh, India*

ABSTRACT

Water is essential for agricultural production, and modern irrigation practices emphasize feeding the root rather than merely the crop. Recent advancements, particularly in micro-irrigation systems like laser spray and rain port irrigation, have shown improved efficacy over traditional methods. This research paper investigates the performance and irrigation dynamics of two emerging micro irrigation systems, laser spray, and rain port systems, in enhancing water use efficiency in agricultural practices within Andhra Pradesh, India. The study is anchored in the context of the increasing importance of micro-irrigation technologies to improve crop productivity, especially in rainfed conditions. Experimental trials were conducted at two agricultural research stations, Ananthapuramu and Reddipalli, focusing on various performance indicators including Christiansen Uniformity Coefficient, Distribution Uniformity, Coefficient of Variation, and Depth of Irrigation. Results indicate that the rain port system exhibits a higher uniformity and lower coefficient of variation compared to the laser spray system, with mean uniformity coefficients of 86.98% and 79.34% respectively. The distribution uniformity showed that the rainport system maintains better performance consistency across different operational conditions. Furthermore, the study highlights the significance of operational pressure and wind speed on irrigation efficacy, noting that the rain port system's design allows for better water distribution and efficiency in diverse cropping systems. This research underscores the potential of advanced micro-irrigation systems in optimizing water usage and enhancing agricultural productivity, advocating for their wider adoption in sustainable farming practices.

Keywords: *Distribution Uniformity, crop productivity, micro irrigation systems, agricultural productivity.*

Introduction

Water is key for agriculture production and productivity. At the present scenario the irrigation to the crops changed to Feed the Root – Not crop and in future the definition may change to a new direction (5). The productivity of rainfed crops is always dictated by the quantity and pattern of rainfall received during the crop season (6). With the advent of micro irrigation in the recent past the irrigated area increased tremendously in India and particularly in Andhra Pradesh. Though the existing micro irrigation systems are working at best of its performance still there is a dire need to increase the application efficacy, precession and adoption to the diversified crops. Laser and rain port irrigation systems were recently emerged micro irrigation systems with better performance than the existing drip and sprinkler micro irrigation systems (3,4). Laser and rain port systems have an edge-cutting advantage over the existing micro irrigation systems (sprinkler and drip) in terms of cost, ease of operation, water use efficiency, etc. Furthermore, they can be adopted for a wide range of crops, like both agriculture and horticulture, and other micro irrigation systems with single-man handling operations (2). With the advent of more precession, it is better to adopt in wide range of crops which enables to increase the area under micro irrigation reaps higher yield and profits.

Corresponding Author: **Y. Pavan Kumar Reddy*

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Because of the above experimentation was executed on laser and rain port irrigation systems field performance and irrigation dynamics at two locations.

Techniques

The experimentation was executed at two locations viz., Agriculture Research Station, Ananthapuramu, Acharya N.G.Ranga Agricultural University of the Andhra Pradesh situated at 14^0 41' latitude,77^0.40' longitude with an altitude of 355 m above mean sea level and Agriculture Research Station, Reddipalli, Acharya N.G.Ranga Agricultural University of the Andhra Pradesh situated at 14^0 72' latitude,77^0.66' with a mean sea level of 352m. The experiment was executed at ARS, Ananthapuramuin the rainfed *alfisols* with sandy loam of sand 84.20 %, silt 3.20 % and clay with 12.10 % and at ARS, Reddipalli with is also comprised of red sandy loam with sand 85.21 %, silt 3.45 % and clay with 11.34 %. Before the experimentation soil moisture constants of the both sites were estimated. At ARS, Anantapuramu and ARS,Reddipalli. Rain pipe/laser spray and rain port systems were installed in 1 ha of area for the experimentation and evaluated at the initial, middle and fag end of each system for various parameters. During the experimentation, the wind speed was 12 kmph at Agricultural Research Station, Ananthapuramu and 11 kmph at Agricultural Research station, Reddipalli.

Rain Pipe or Laser spray

It was installed in 1ha of land with sub main of flex net pipe with 64 mm diameter connected to 10 hp motor for the irrigation discharge. From the sub main the rain pipe/ laser spray of 32 mm was spaced at 5 m distance row to row apart with the running length of 50mm of each laser spray pipe line. A matrix of catch cans was installed at starting 0 m from the rain pipe/ laser spray to 10 m of the laser pipe length and in between the row spacing for every metre catch cans were kept and installed flat to the ground before the estimation of the water dynamics to the system. The catch can grid was at 1 m x 1m in the 0-10m, 25-30m and 45-50m for the rain pipe system at both the locations of the experimentation.

Rain port system

Rain port system was installed in 1 ha of land with row-to-row spacing of 8m for the sub mains with the LDPE 32 mm. The main line with 64 mm PVC pipe connected to 10 hp motor for the discharge. In the sub the raisers or riser head/ rain ports were placed 8 m apart from each other for the discharge. Total of 80 catch cans were placed at 1m x 1m around each raiser. The catch cans were placed at initial, middle and end the sub-line for the raisers. The experimentation was executed at both locations.

Christiansen Uniformity coefficient

A measurable index of degree of uniformity obtained from any size of sprinkler operating under given condition is known as uniformity coefficient. The uniformity coefficient was obtained by the following formula proposed by Christiansen. (3). It is expressed by the

$Uc = 100(1.0 - \sum x/mn)$

Where Uc = Uniformity coefficient developed by Christiansen, %

x = Absolute deviation of the individual observations from the mean, mm

m = Average value of all observations, mm

n = Number of observations

Distribution uniformity / Pattern efficiency

A useful term for placing a numerical value on the uniformity of application for irrigation system is the distribution uniformity (Du). The distribution uniformity is also known as pattern efficiency (Pe). It indicates the uniformity of water application throughout the field and is computed by,

D_u = Minimum Depth / Average depth

D_u = <u>Volume accumulated in 25 % area of the total of all the elements with smallest depths</u>

Total area of 25 % the total area of the elements

The minimum depth is calculated by taking the average of the lowest 1/4th of the can used in a particular test.

Coefficient of variation

The coefficient of variation (CV) is the quotient between the standard deviation of the applied water depths (σ) and the average of water depth collected according to ASAE (1991).

$CV = \sigma / \mu$

Where σ = Standard deviation of the water depth of catch-cans

μ = Mean of all water depth of catch-cans, ml

Depth of irrigation

Depth of irrigation or quantity of the irrigation applied to the field was a key factor to know the irrigation hydraulics or dynamics. The total discharge over one-hectare land area was brought to the calculation using the discharge with area.

Statistical uniformity

The SU is usually used to represent the uniformity of microirrigation systems, such as drip and micro-spray systems. The CU and DUlq can also be expressed in terms of CV if a normal distribution is assumed for the distribution of water. These are the statistically derived estimates for the uniformity. The statistical estimates for the coefficient of uniformity (SCU) and the low quarter distribution uniformity (SDUlq) are given by (2):

$SCU = 100 (1 - 0.798\, CV)\ \%$

$SDUlq = 1 - 1.27\, CV$

Mean application rate

Mean application rate is the depth of water applied by the rain pipe on the soil surface per unit of time. It was estimated according to the following formula,

$I = \sum X\, n \times t$ Where I = application rate, mm/h

∼ ΣX = Total depth of water collected in the catch cans (volume/area of can), mm

n = number of catch cans t = time of operation, h

Results/ Effects

Christiansen Uniformity coefficient

Laser spray/ Rain pipe irrigation

The parameters were analysed at two different research institutes with almost same conditions viz.Agriculture Research Station, Ananthapuramu&Reddipalli of Acharya N.G. Ranga Agricultural University of the Andhra Pradesh with laser spray and rain port irrigation systems. The results indicated that the mean uniformity across the 50 meters of the running length was 79.34 in both the site of experimental location. Bhadarka*et al*., 2023 reported that average uniformity at 5 m later spacing was 79.58. The slight declines the uniformity was reported due to the wind speed of 12 kmph displaced the water and reduced the uniformity of the entire system. However, the uniformity was higher (85.20) in first 15m running length of the pipe compared to the fag end (74.05) of the running length in the laser spray system. The variation across the running length was due to the variations in pressure of the rain pipe system which vas varied by the discharge factor of the motor.

Rain port irrigation system

In the rain port system of irrigation uniformity studies were executed at start of sub main, mid, and fag end of the main like with 2^{nd} raiser head across the two locations. The overall mean of Christian uniformity was 86.98 at two experimental locations. In the rain port system the higher uniformity was due to larger droplet size compared to laser spray/rain pipe irrigation. With the rain port irrigation systems at start of the sub-main line 93.8 uniformity was recorded whereas at the fag end the uniformity was 86.98. Further there was no much variation was observed across the 50 m running length of sub main line.

Table: Christiansen Uniformity coefficient of laser spray and rain port irrigation systems

Institute	Laser spray				Rain port irrigation			
	Initial (0-10m)	**Mid (20-30m)**	**End (40-50m)**	**Mean**	**Initial (0-10m)**	**Mid (20-30m)**	**End (40-50m)**	**Mean**
ARS, Aanthapuramu	80.20	79.3	78.2	79.23	95.9	93.4	92.1	93.80
ARS, Reddipalli	90.21	78.2	69.9	79.44	80.4	80.1	80	80.17
Average	85.20	78.75	74.05	79.34	88.15	86.75	86.05	86.98
SD	5.01	0.55	4.15	0.10	7.75	6.65	6.05	6.82

Distribution uniformity/ Pattern efficiency

Distribution uniformity was estimated for both the laser spray and rain port irrigation systems to identify the uniformity of the irrigation discharge and also the water availability across the fields in the two locations of the experimental sites.

Laser spray

The parameters were examined at two distinct research institutions under almost identical conditions, namely the Agriculture Research Station in Ananthapuramu and Reddipalli of Acharya N.G. Ranga Agricultural University in Andhra Pradesh, utilizing laser spray and rain port irrigation methods. The results demonstrated that the average Distribution uniformity/ pattern efficiency was 67.37 % at both testing locations. The pattern efficiency/distribution efficiency was almost similar in both locations. The deviation of the pattern efficiency was slightly higher at initial and fag end of the system. The overall mean deviation was 0.1 which is very less indicating that irrigation system working at best performance at both the locations.

Rain port irrigation

Concerning the rain port irrigation the average distribution pattern of the irrigation was 80.47. The deviation of the system performance was 8.13 which is higher in number indicating the performance of the system which was deviating at locations. The deviation in system due to variation in the wind velocities, climatic conditions, motor discharge rate and pump pressure. The deviation rate was similar across the running length. It indicated that though the pattern efficiency was less but it is uniform across the system.

Table: Distribution uniformity/ Pattern efficiency of laser spray and rain port irrigation systems

Institute	Laser spray				Rain port irrigation			
	Initial (0-10m)	**Mid (20-30m)**	**End (40-50m)**	**Mean**	**Initial (0-10m)**	**Mid (20-30m)**	**End (40-50m)**	**Mean**
ARS, Aanthapuramu	73.2	65.4	63.2	67.27	87.2	88.9	89.7	88.60
ARS, Reddipalli	82.1	62.1	58.2	67.47	73.2	72.2	71.6	72.33
Average	77.65	63.75	60.7	67.37	80.2	80.55	80.65	80.47
SD	4.45	1.65	2.50	0.10	7.00	8.35	9.05	8.13

Coefficient of variation

The Coefficient of variation was studied across the locations and it was varied with the system performance. Coefficient of variation across the systems or study location indicating the consistence in performance of the system. Among the two systems performance coefficient of variation was higher laser spray irrigation system (38.18) rather than rain port irrigation system (24.88).

Laser spray

In the laser spray irrigation system, the mean coefficient of variation was 38.18 percent and within the two location the coefficient of variation was higher at fag end (40.65) and it was low at start point (35.98). which indicates that the discharge was varied or discharge was varied two different locations of the system. The coefficient of variation was varied across the locations due to the discharge of the pump lead to uneven pumping and out put at fag end of the location.

Rain port irrigation

Coefficient of variation was less in rain port irrigation system compared with the laser spray system due to less no of discharge units the variation was less or half of the rainport irrigation systems. The overall mean coefficient of the variation was 24.88 in the rain port irrigation system. With the irrigation of the rain port system the variation was very less from start point to the flag end indicating the system was uniform across the locations.

Table: Coefficient of variation of laser spray and rain port irrigation systems

Institute	Laser spray				Rain port irrigation			
	Initial (0-10m)	**Mid (20-30m)**	**End (40-50m)**	**Mean**	**Initial (0-10m)**	**Mid (20-30m)**	**End (40-50m)**	**Mean**
ARS, Aanthapuramu	38.70	40.20	43.10	40.67	21.03	20.02	19.84	20.30
ARS, Reddipalli	33.25	35.60	38.20	35.68	29.3	30.2	28.9	29.47
Average	35.98	37.90	40.65	38.18	25.17	25.11	24.37	24.88

Table: Depth of irrigation in laser spray and rain port irrigation systems

Institute	Laser spray (mm/hr)				Rain port irrigation (mm/hr)			
	Initial (0-10m)	Mid (20-30m)	End (40-50m)	Mean	Initial (0-10m)	Mid (20-30m)	End (40-50m)	Mean
ARS, Aanthapuramu	24	25	24	24.33	8	8.1	8	8.03
ARS, Reddipalli	32	31	27	30.00	8.5	8.4	8.4	8.43
Average	28	28	25.5	27.17	8.25	8.25	8.2	8.23
SD	3.27	2.45	1.22	2.31	0.20	0.12	0.16	0.16

Depth of Irrigation

Laser spray/ Rain pipe irrigation

The mean depth of irrigation was 27mm/hr in the laser spray/ rain pipe irrigation system at an operating pressure of 1.5 kg/cm^2. There was no much variation till 30 m of rain pipe length in the mean depth of the water discharge at two experimental locations. However, there was the decline of 3 mm discharge at fag end of the laser/rain pipe irrigation systems due to variation in the pressure across the pipe in the system. Depth of irrigation was slightly higher (30 mm) at ARS, Reddipalli compared to second experimental location (ARS, Ananthapuramu – 24 mm) due to the well maintenance of pressure in the rain pipeline across the system. Though there was variation in the discharge depths of the irrigation 27mm/hr mean discharge depth is very efficient for the function of the rain pipe/ laser spray system.

Rain port irrigation system

Rain port irrigation is discharging on average of 8.2mm/hr at operation pressure of 2 kg/cm^2 with a discharge of 1050 lph per rain port head compared to sprinkler head which is discharging 1800 lph in both locations of the experimentation. Rain port discharging 2mm/hr less water discharge compared to sprinkler irrigation system. Further add on to this there was uniform discharge of the rain port raiser head across the running length of the system indicting the best performance of the system.

Table: Width of coverage by laser spray and rain port irrigation systems

Institute	Laser spray (m)				Rain port irrigation (m)			
	Initial (0-10m)	Mid (20-30m)	End (40-50m)	Mean	Initial (0-10m)	Mid (20-30m)	End (40-50m)	Mean
ARS, Aanthapuramu	6.0	5.9	5.9	5.9	8.2	8.2	8.1	8.16
ARS, Reddipalli	6.0	5.9	5.8	5.9	8.5	8.4	8.4	8.43
Average	6.0	5.9	5.85	5.9	8.35	8.3	8.25	8.3
SD	0.00	0.00	0.04	0.00	0.12	0.08	0.12	0.11

Width of coverage or Horizontal throwing radius

Width of coverage was the one of the key dynamic factors, which impacts the distribution and uniformity aspect in the large scale. Horizontal spread/ Width of coverage will be major deciding factor with respect to uniformity.

Width of the coverage or Horizontal throwing radius by one Laser spray/ Rain pipe

The discharge range/ width of the laser pipe was horizontally measured at three locations viz., initial, middle and final as indicated in the table. The width of coverage was 6 m,5.9m and 5.9mhorizontally by the laser spray/rain pipe system at 0-10 m ,20-30m, 40-50m running length respectively. The mean width of coverage horizontally was 5.9m. It was noticed that on average the standard deviation was almost zero which indicates working same with all the distances concerning horizontal spread.

Width of the coverage by one Rain port raiser

The discharge range/ width of the rain port was measured at three locations viz., initial, middle and final as indicated in the table. The width of coverage was 8.35m,8.3m and 8.25 m by the rain port irrigation system at 0-10 m ,20-30m, 40-50m running length respectively. The mean width of coverage was 8.3 m. It was noticed that on average the standard deviation was almost zero which indicates working the same with all the distances concerning horizontal spread.

Statistical uniformity

Laser spray and Rain port irrigation system

The mean water discharge of statistical uniformity was was 61.83 mm/hr observed in laser spray irrigation whereas in rain port irrigation was 75.12 mm/hr. The mean discharge was lower in laser spray compared to the rain port irrigation. The highest discharge was observed at initial (0-10 cm) *i.e* 64.03 followed by mid (20-30 cm) and at end (40-50 cm) *i.e* 62.10 and 59.35 respectively in laser spray irrigation. The variation was very less in rain port irrigation from start point to the tail end point and it is lowest at initial (0-10 cm), followed by mid (20-30 cm) and end (40-50 cm) *i.e* 74.84 mm/hr, 74.89 mm/hr and 75.63 mm/hr respectively. The average standard deviation was lowest in laser spray irrigation compared to rain port irrigation.

Table: Statistical uniformity of laser spray and rain port irrigation systems

Institute	Laser spray				Rain port irrigation			
	Initial (0-10m)	Mid (20-30m)	End (40-50m)	Mean	Initial (0-10m)	Mid (20-30m)	End (40-50m)	Mean
ARS, Aanthapuramu	61.30	59.80	56.90	59.33	78.97	79.98	80.16	79.70
ARS, Reddipalli	66.75	64.40	61.80	64.32	70.70	69.80	71.10	70.53
Average	64.03	62.10	59.35	61.83	74.84	74.89	75.63	75.12
SD	2.22	1.88	2.00	2.04	3.38	4.16	3.70	3.74

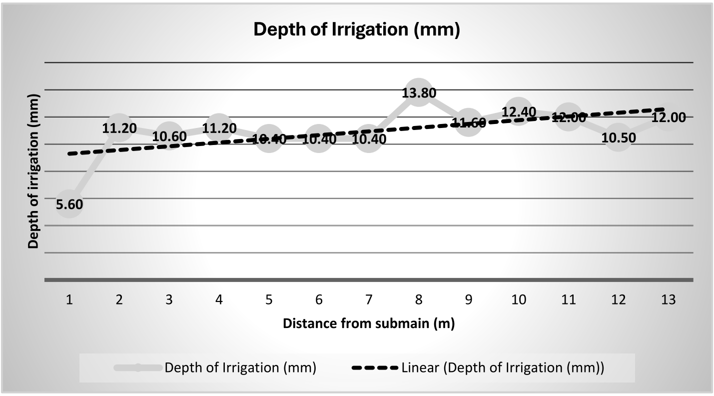

Fig: 1. Depth of irrigation in the laser spray irrigation system across the varied lengths

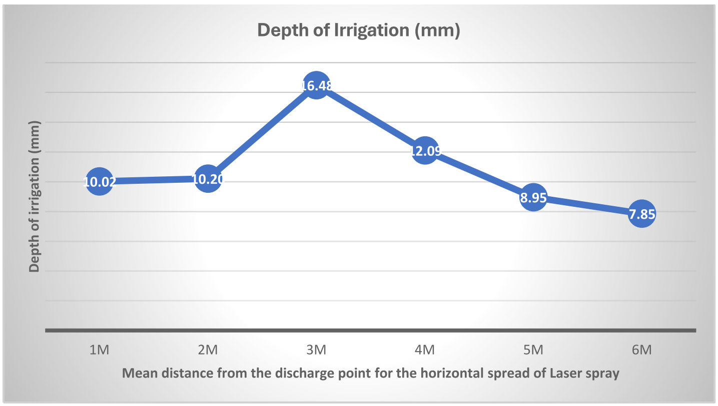

Fig: 2. Depth of irrigation in the laser spray irrigation system across the varied lengths

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