EFFECT OF EMITTER DENSITY ON YIELD AND WATER PRODUCTIVITY OF WHEAT UNDER DRIP IRRIGATION IN NORTH BIHAR CONDITION

A THESIS

Submitted to the Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar in partial fulfilment of the requirements for the Degree of

MASTER TECHNOLOGY

in

SOIL AND WATER ENGINEERING

By

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Dated: 19.09.2020

Certificate

This is to certify that the work recorded in this thesis entitled "**Effect of Emitter Density on Yield and Water Productivity of Wheat under Drip Irrigation in North Bihar condition**" submitted in the partial fulfillment of the requirements for the award of the degree of **MASTER OF TECHNOLOGY** in **Agricultural Engineering** in the Department of **Soil and Water Engineering** of the Faculty of Post-graduate Studies**,** Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar is the faithful record of **bonafide** research work carried out by **Ms. ANJALI KHANDEKAR (MT/SWE/324/2018 - 19)** under my supervision and guidance.

No part of this thesis has so far been submitted for any other degree or diploma. The assistance and help received during the work and source of literature have been duly acknowledged.

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Place: Pusa

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LIST OF ABBREVIATIONS

B D	bulk density
B C	benefit - cost
C_v	coefficient of manufacture variation
Cm	Centimetre
cm^2	square centimetre
CAE	College of Agricultural Engineering
CV	coefficient of variance
DI	drip irrigation
E	East
EC	electrical conductivity
e.g.	for example
et al.	and others
ET	evapo-transpiration
ET_c	crop evapo-transpiration
E_u	emission uniformity
Fig.	Figure
Gm	Gram
GMR	Gross monetary return
Ha	Hectare
Hr	Hour
i.e.	that is
ISO	International Organization for Standardization
K_c	Crop coefficient
K_p	Pan coefficient
kg	Kilogram
kg/cm^2	kilogram per centimeter square
kPa	kilo Pascal
LAI	leaf area index
Lph	liter per hour

LDPE	low density poly ethylene
M I	micro – irrigation
M. B.	mould board
MRL	meter row length
Mha	million hectare
N	North
No.	Number
NMR	Net monetary return
PE	Precision Farming Development Centre
PMKSY	Pradhan Mantri Krishi Sinchai Yojna
PVC	Poly Vinyl Chloride
PWP	permanent wilting point
q/ha	quintal per hectare
RPCAU	Rajendra Prasad Central Agricultural University
Rs.	Rupees
SEm±	Standard error of mean
WUE	Water use efficiency
WP	Water productivity

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ABSTRACT

Maximum the grain yield with minimum expenses is the most challenging factor in the progressing countries like India. Therefore, the main focus of this work was to estimate the wheat yield response to different lateral and dripper spacing combination in drip irrigation system. A field experimentation was organized in the experimental farm of PFDC, College of Agriculture Engineering, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, to study the "Effect of Dripper Spacing on Yield and Water Productivity of Wheat under Drip Irrigation". Result found that 23.99% water saves in drip irrigation system contrasted to supervised pipe irrigation. The wheat grain yield was 7.34% and 1000 grain weight was 3.57% more than supervised pipe irrigation. The maximum grain yield was found 46.37 q/ha in 30cm lateral spacing and 30cm dripper spacing. Water productivity of drip irrigated wheat was 19.04% more than the supervised pipe irrigated wheat. The conclusion made with this study was drip irrigation system with 30cm lateral spacing and 50cm dripper spacing shows most suitable result. This combination shows economical result. Thus, drip irrigation system is more efficient with less water than supervised pipe irrigation system.

CHAPTER - I

INTRODUCTION

INTRODUCTION

Wheat is the most commonly grown crop in the world. Wheat is not only a major source of food but also a plant that is important for food security nationally due to its outstanding share in grain stocks. Therefore, it plays an important role in the national food supply chain which should play a major role in stabilizing grain production in the country at increasing rates. It contains gluten-free cereals with chemical and non-chemical properties. The gluten content in wheat is high (12 - 14%) compared to all other food grains and very high in grains. Due to the presence of gluten its flour is used to bake bread which is the major food for more than half of the world's population.

In India, wheat is the most important food crop after rice. After China, India is the second largest grower of wheat reported as 8.70% of global wheat production. In India, wheat shares 13% of arable land (29.58 million hectares) with 99.7 million tons of production and 33.71 q / ha (2017-2018, Annual Report, DAC and FW). Significant increases in wheat production have been observed in the Haryana, Punjab, and Uttar Pradesh regions. In Bihar crop production is 59.89 million tons and 21.06 million hectares of land with an average yield of 2843 kilograms per hectare in 2016-17. (Directorate of the Department of Economics and Exploration, Govt. of Bihar).

However, efforts have been made to increase wheat production to feed the growing population; much remains to be done. During rabies the sub-wheat area decreased by 1% to 2.3 m ha. India needs 110 million tons of wheat grain this year i.e. 2020 and there is little chance of horizontal expansion in the wheat field. Therefore, a large portion of the required demand will have to be met by increasing productivity to maximize sustainable production. Production growth should be done within a limited area, because the land is not expandable. Our main task is to increase productivity with this limited land. By increasing yields, irrigation plays an important role. But we cannot ignore the problem of water scarcity. Annual rainfall of India is about 1200 mm. However, it is vital to record that rainfall does not only occur within 4 months of the year but that the distribution of rainfall locally and temporarily varies so much that the annual average is of very low importance for all practical motives. In reality, one third of the world's land remains at risk of drought not only because of insufficient rainfall but also because of its unequal distribution. Growing more plants from shallow water is a challenge that we will still face using integrated irrigation water management methods with increasing water production. Therefore, irrigation should be done with this problem. So our second job is to increase production by less water.

In our country India, much of the farming area of wheat crop is irrigated by floodwaters, with more water use. Low quality water containing wastewater and clean wastewater have become an important source of irrigation due to its nutritious and easily accessible content. Available estimates show that the efficiency of water under irrigation system is only 35 to 40 percent due to significant losses of distribution and distribution (Chouhan.S. S. *et al.*, 2014). In terms of agriculture, India's water resources are under tremendous pressure.

With the agricultural sector consuming 80% of India's freshwater, small-scale irrigation is often promoted by central and local governments as a way to address the growing water crisis. This is because drip irrigation and spraying bring water to farms at much lower rates than conventional irrigation. Due to the frequent droughts in 2012, 2015 and 2016, low irrigation has become a priority policy in India. A new slogan for the capture of one of the Supreme Government schemes, Pradhan Mantri Krishi Sinchai Yojana (PMKSY), is "Per Drop More Crop". Clearly, switching to less irrigation is thought to “save” water and increase crop yields.

The Government of India is committed to promoting water conservation and management. As a result, PMKSY has been established with the aim of expanding access to irrigation and improving sustainable water use and end-to-end solutions for resource construction, distribution, management, field use and extension activities. PMKSY's main objective is to achieve a combination of investment in field irrigation, improve farm water availability and increase arable land under guaranteed irrigation (Har Khet Ko Pani), improve farm water use to reduce water wastage, improve precision irrigation adoption and other water conservation technologies (Per Drop More Crop), has improved aquiferi rehabilitation and introduced sustainable water conservation measures by assessing the potential use of municipal wastewater for agricultural use in urban areas and attracting more private investment in an accurate irrigation system. The program also aims to bring Ministers / Departments / Agencies / Research and Finance Institutions involved in the creation / use / recycling / reuse of water, brought under the same platform, so that a complete and complete view of the entire "water cycle" is considered and a proper water budget is being developed for all sectors, namely, domestic, agricultural and industrial

Agriculture the largest water user; these waters are subject to intense competition with other sectors. Water is a valuable national resource and there are many concerns about water resources in the country. Improving plant water efficiency is a matter of time. At the same time, increasing crop production to increase the efficiency of irrigation water is very effective

Keeping the above in view, an attempt has been made to study the effect of emitter density on yield and water productivity of wheat crop under drip irrigation in North Bihar condition.

The objectives of the study are as follows:

1. To work out the water requirement of wheat crop.
2. To study the effect of different combinations of lateral and emitter spacing on grain yield.
3. To work out the water use efficiency and water productivity of wheat crop under drip irrigation system.
4. To work out cost economics.

CHAPTER - 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A comprehensive review of literature is an essential aspect of any scientific investigation and provide an insight on the theoretical frame work as well as methods, procedure and meaningful interpretation of findings. In this chapter, a review of current status of literature related to the current study has been presented. The review is dealt under the following subheadings:

2.1 Wheat crop response under drip irrigation

Clinton *et al.* (2005) reported that biomass dry yield and grain yield was less suitable beginning at 65 cm from the laterals because of fragmented lateral motion of the irrigation water. There turned into upward push in water use efficiency with the depletion in consistent with cent ETc changed from 100 in step with cent to 80 in line with cent. Water use efficiency for 60 in line with cent ETc treatment become near the 80 in step with cent ETc treatment.

Liao et al. (2008) acknowledged a courting between soil water consumption and the irrigation quantity, crop yield and water use efficiency. It was resulted that for elevated crop yield, it's far crucial to keep exceedingly high soil water content for the duration of the 2 sensitive boom ranges: elongation and milky filling stages. It became resulted that with drip irrigation higher yield observed although a great deal, much less water was used than what turned into utilized in block irrigation test.

Arafa *et al.* (2009) estimated the wheat yield response to drip irrigation structures and noted that 26.57 % of wheat grain yield had been reduced under the opportunity irrigation structures (sub-floor and surface drip) differentiated with the solid-set sprinkler irrigation gadget. Even then, water use performance and water saving have been expanded with 43.13 % and 76 %, respectively when drip irrigation systems had been used.

Rahman (2009) conducted two years' field experiment to study on grain yield of 3 wheat sorts as suffering from four irrigation implemented prices by of four lph to eight lph on one line and on strains and located that grain and straw yields of wheat had been extended with drip irrigation on the 2 lines of the laterals with 4 lph utility rate.

Wang *et al.* (2009) studied the outcomes of two extraordinary irrigation methods, this is, stage-basin irrigation (BI) and drip irrigation (DI), and exclusive remedy stages on crop growth, yield, and WUE of iciness wheat. The effects imply that irrigation methods and treatment levels had enormous consequences on crop boom and yield of wintry weather wheat. Irrigation quantities notably prompted plant heights, leaf vicinity index, and grain yields for each irrigation methods. Further, the DI approach notably advanced yield and WUE compared with the BI approach underneath situations of deficit irrigation.

Kharrou *et al.* (2011) discovered the drip irrigation scheduling changed into more green with water saving of approximately 20% comparatively to surface irrigation with the full irrigation method, the grain yield in drip irrigation become 24 % better than complete irrigation remedy and 59 % better than the present rule remedy and the WUE become stepped forward by means of 52 % and 28 % while in comparison with the prevailing rule and complete irrigation remedies respectively.

Chauhan and Yadav (2012) conducted a study to look on water and nitrogen variables in 4 equal spaced nitrogen ranges (60, 90, 120 and 150 kg N/ha) for wheat, and it result found was the yield of wheat recorded at 46cm to 50cm water software inside the crop fertilized with 150 kg N/ha. In 35 cm to 45 m water, 120 kg N/ha was found the most efficient. 90 kg N/ha application of fertilizer found sufficient with 30 cm to 34 cm of irrigation water for wheat crop.

2.2 PLANT HEIGHT

A progressive and significant rise in crop height with increase in the number of irrigation and due to method of irrigation (Verma *et al.* 2003). Drip irrigation in corn recorded higher plant height (182 cm) as compared to surface irrigation (Dilip and Madakini, 1993). Daeood and Kheiralla (1994) stated that higher irrigation treatment had significant effect on plant height. Hence plants were taller due to increase in irrigation level (Hooda and Agrawal, 1987). The result of experiment conducted by Vijaykumar (2009) in Tamilnadu found the drip irrigation at 150% PE in hybrid rice exhibited better plant height (104.8 cm) than that of irrigation at 100% PE . Likewise, increased plant height (103.6 cm), in aerobic rice with irrigation scheduled at 150% PE (Govindan and Grace, 20120.

2.2.1 Leaf Area Index

Surface drip irrigation and sub-surface produced significantly higher LAI than furrow irrigation in cotton grown in vertisols of Narrabari, Australia (Constable and Hodgson, 1990). Vijaykumar (2009) in hybrid rice also found that drip irrigation at 150% PE recorded better leaf area index than that of irrigation at 100% PE.

2.2.2 Number of Tillers

The highest tillers production in wheat was recorded with drip irrigation as compared to surface irrigation (Mahadi *et. al.* 1997). Further; he reported that tillers production in spring wheat growth rises rapidly with the increment in water application rate, till 1.0 ET. Likewise, Vijaykukmar (2009) and Govindan and Grace (2012) found that drip irrigation at 150 % PE in hybrid rice exhibited better number of tillers than that of irrigation at 100% PE.

2.3 EFFECT OF DRIP IRRIGATION ON YIELD ATRIBUTES

2.3.1 Number of Ears (m^{-2})

Abd EI-Rahman (2009) conducted an experiment on drip irrigation in Cario, Egypt, and stated that crop receiving drip irrigation with application rate of 8 Lph on two lines (S_4) recorded higher number of ear m^{-2} followed by one line(S_2) and 4 lph with one (S_1), two lines (S_3) due to higher frequency of irrigation. These outcomes are tune with the results of Kruse *et al*. (1990) and Henggeler (1991).

2.3.2 Grain Yield

Drip irrigation at 150 % CPE found notably higher grain yield (5680 kg/ha) of rice. This rise in yield is attributing to higher number of productive tillers (593 per m^2) and harvest index (0.45) in hybrid rice (Vijaykumar, 2009). Similarly, Govindan and Grace (2012) also observed higher grain yield (4986 kg/ha) of aerobic rice due to drip irrigation scheduled at 150 % PE.

Clinton *et al.* (2005) conducted an experiment at Malheur experiment station, Ontario, Oregon on wheat and recorded the highest grain yield of wheat with drip irrigation scheduled at 100 % ETc which was at par with 80% ETc than that of 60 % ETc. Similarly Mahadi *et al.* (1997) also reported same result with drip irrigation at 1.0 ET compared to deficit irrigation.

2.4 EFFECT OF DRIP IRRIGATION ON WATER PRODUCTIVITY AND WATER REQUIREMENT

2.4.1 WATER PRODUCTIVITY

Water productivity of wheat decreases with increases in irrigation at excessive stage preliminary soil water (75% EW), at the same time as at low preliminary soil water (25 %), water productivity will increase from Io to Ip regime, and decreases thereafter with extra irrigation (Arora *et al.* 2007). A negative correlation and consequences imply by the water productivity curve which indicates the reduced water application growth water productivity. This indicates the water productivity had been encouraged by the irrigation techniques and irrigation deficiency is efficiently encouraged the efficiency of irrigation water. In subject studies, it has been amply shown that the water productiveness of wheat in alluvial soils of Punjab was extra while medium or high initial soil water conditions were blended with fewer posts sowing irrigations regimes (Pirhar and Jalota *et al.* 1980).

Clintone *et al.* (2005) at Malheur experiment station, Ontario, Oregon from drip irrigation experiment results concluded on wheat that there was a noticable rise in water productivity with the decrease in ETc replaced from 100 % to 60 %. The higest water productivity was recorded in 60 % ETc which was on par with 80 % ETc.

Kamilov *et al.* (2004) stated that drip irrigation resulted in saving up to 22 % of irrigation water and increased the WP by 10.1 to 35 % on comparison with furrow irrigation at irrigation scheduling of 70-80 % of field capacity i.e. (Germination to tillering stage, shooting to milky-wax stage and maturation) during crop growing season.

Doorenbos and Kassam (1986) reported that the water utilization efficiency for harvested yield of wheat seed containing 12 to 15 % moisture is about 0.8 to 1.0 kg/m^3.

2.4.2 WATER REQUIREMENT

The rate of consumptive water use (mm/day) increased with crop age and reached its peak during first fortnight of February (boot to flowering) and declined thereafter indicating that the boot to flowering period of wheat growth must match its adequate irrigation supply. Water use rate at different growth stages depends not only on the transpiration but also on the evaporative demand of the atmosphere (Pal *et al.*1996, 2001).

Panda *et al.* (1998) at Chiplima, in sandy loam soil of Orissa revealed that the consumptive use of water varied from 26.65 to33.81 cm within the range of moisture regime from 0.6 to 1.0 IW: CPE ratio. The highest water requirement of 33.18 cm, 37.33 cm, and 37.91 cm were recorded from the treatment where irrigation was applied at 1.0 IW: CPE ratio during 1980, 1981 and 1982 respectively. Optimum water requirement was about 35 cm.

Shao *et al.* (2009) observed that periodic water use of wintry weather wheat crop under confined water supply at the range of 330 - 340 mm in 2002 - 03, 470 - 520 mm in 2004 - 04, 340 - 390 mm in 2004 - 05, 310 - 330 mm in 2005 - 06 mm and 390 - 440 mm in 2006 - 07. Likewise, 323 mm with five irrigation schedule (I5) became more because of frequent irrigation closely observed by means of 300 mm (I_4), 256 mm (I_2) and 158 mm (I_1) irrigation schedule become pronounced by Pal *et al.* (1996).

The coefficient pf uniformity is found more in surface irrigation by approximately 4.40 % than drip irrigation. It is found that a term used with the soil moisture content is a vital application in the calculation of soil wetting pattern with each drip irrigation and surface irrigation systems. The founding of this work can be used for the design, operation and control of drip irrigation and surface irrigation systems.

CHAPTER - 3

MATERIALS AND METHODS

MATERIALS AND METHODS

To study the effect of dripper spacing on yield and water productivity of wheat under drip irrigation, a study was conducted during the rabi season of year 2019 - 2020. The chapter deals thoroughly about the location of the test site, the texture of the soil and the various materials used fir testing. This chapter also deals with the methodology and structure of the set to achieve the objectives of the project work.

3.1 Study area

3.1.1 Location of experimental filed

Field trial conducted during the rabi 2019 - 2020 at the experimental farm of PFDC, College of Agriculture Engineering, RPCAU, Pusa, Samastipur, Bihar. The field has uniform topography with deep and well drained sandy soils.

3.1.2 Soil

The soil developed by sediments deposition of the river of Burhi Gandak. The soil consists of 46.85 per cent sand, 41.35 per cent silt and 11.80 per cent of silt and type of soil is sandy loam. The values of pH, EC, bulk density and organic carbon are presented in Table 3.1.

Table 3.1: Physical properties of soil

S. No.	Soil properties	Values
1	Type of soil	Sandy loam
	a. Sand (%)	46.85
	b. Silt (%)	41.35
	c. Clay (%)	11.80
2	Bulk density (g/cm^3)	1.46
3	pH	8.4
4	EC (dsm^{-1})	0.79
5	Organic carbon (%)	0.41
6	Field capacity	23.50

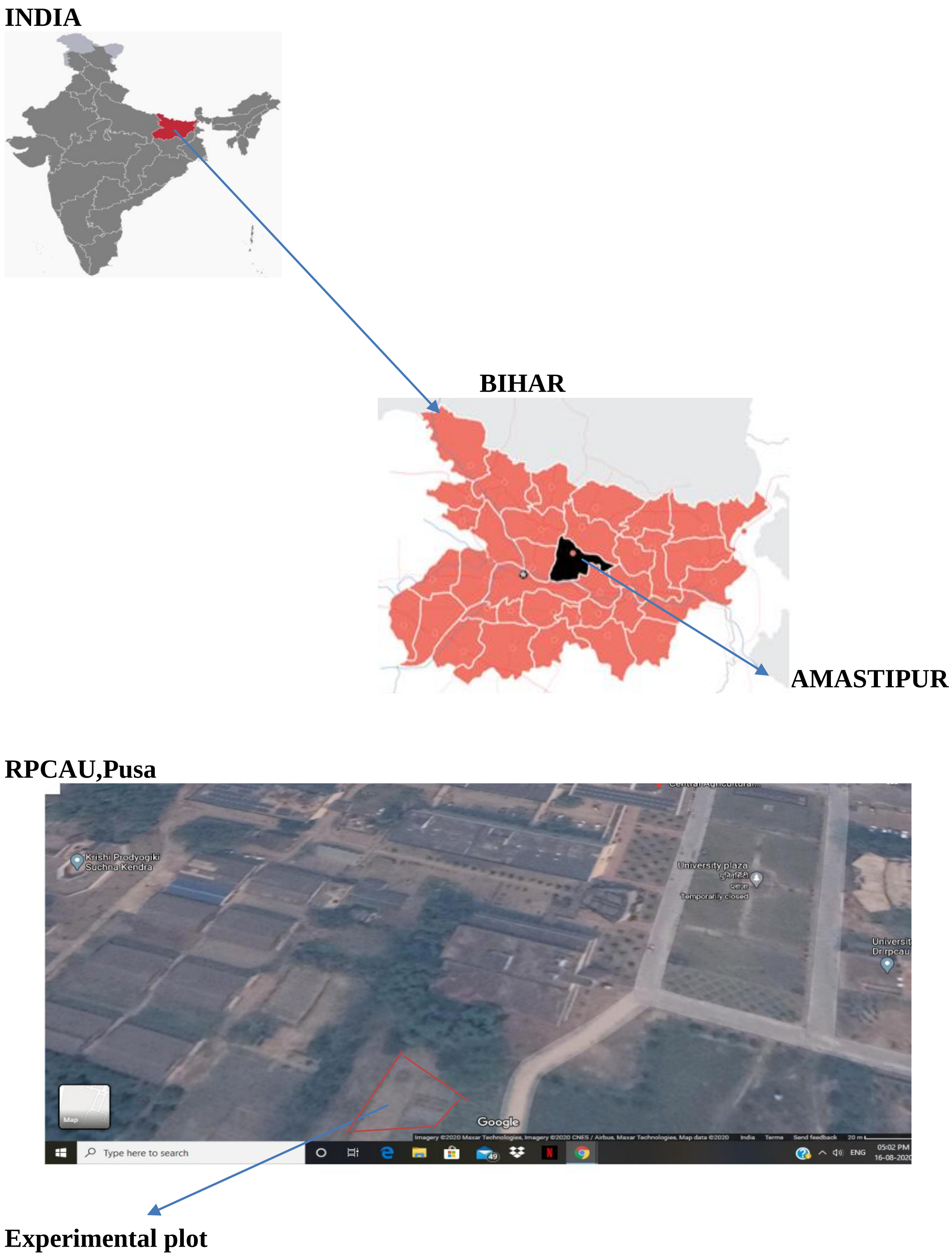

Fig. 3.1: A view of experimental site, RPCAU, Pusa, Samastipur

3.1.3 Climate

The climate of study area is humid subtropical and experimental site was located on the PFDC experimental farm, CAE, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. It lies at 25^{o}59' N at latitude, 85^{o}48' E longitude and at the about 52.92 m above sea level. The annual rainfall (average) is 1326 mm; approximately 1052 mm is received throughout the time of strom. The highest temperature goes up to 42 ℃ during May - June and minimum temperature goes down to 2 - 3 ℃.

3.1.4 Weather condition

Climate data during crop duration (November 2019 to April 2020) of study were taken from the Agro meteorology Division, CASCC, Dr. Rajendra Prasad Central Agricultural University, Pusa. It is shown in Table 3.2 and illustrated with drawings on Fig. 3.2.

Table 3.2: Mean monthly weather information

Month	**Temperature℃**		**RH % at 7 AM**	**RH % at 2 PM**	**Rainfall (mm)**	**Pan evaporation (mm/day)**
	Maximum	Minimum	Maximum	Maximum		
November, 2019	27.86	13.65	92.58	65.58	0.0	1.28
December, 2019	21.00	9.70	92.00	75.00	22.0	1.00
January, 2020	19.60	9.40	92.00	75.00	6.2	1.00
February, 2020	24.60	10.90	92.00	64.00	24.0	1.70
March, 2020	29.00	16.20	86.00	57.00	29.6	2.10

Source: Agro - meteorology Division, CASCC, RPCAU, Pusa

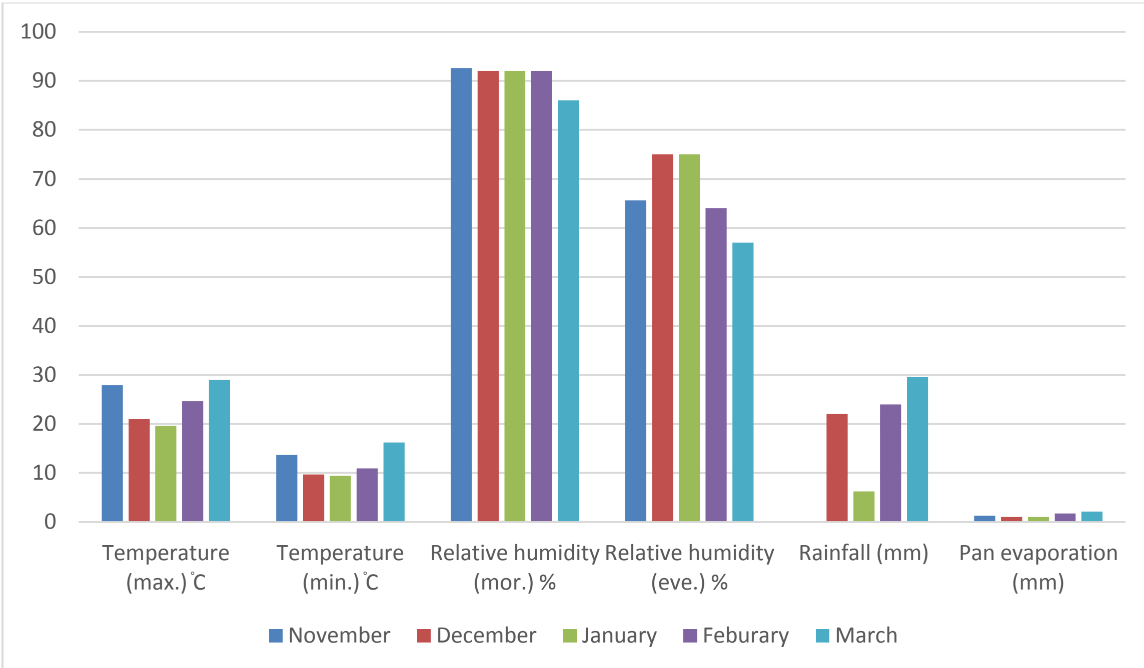

Fig. 3.2: Standard Metrological Monthly (SMM)

3.1.5 Crop

The experimental trial was conducted on Rajendra Genhu-1 wheat. The variety is introduced by RPCAU, Pusa, Bihar. Waxiness is found in the flag leaf, leaf blade and peduncle. Rajendra Genhu-1 has good aversion to leaf and dusts character which are major illness of the central region. It has resistance to leaf damage and kernel bunt. The shape of the grain is round. This variety of plants ripens within 114 days to 122 days, usually within 117 days and reaches a plant height of 85 cm.

3.1.6 Experimental design

The trial was based on the construction of a detached structure and all treatments are tripled. In these two experimental features, a horizontal space was included in the primary treatment and symptom separation in the smaller treatment, resulting in a combination of 9 treatments per block as indicated in the placement program.

3.2.1 Treatment details

A. Lateral spacing – Three (Main plot)

i. T_1 : 30 cm

ii. T_2 : 40 cm

iii. T_3 : 50 cm

B. Emitter spacing - Three (Sub - main plot)

i. S_1 : 30 cm

ii. S_2 : 40 cm

iii.S_3 : 50 cm

C. Control Plot - Border irrigation

3.2.2 Lay out

The test is based on the construction of a split plot design with lateral separation at large sites and emitter separation at the main sites with three responses. The detail design plan of the experimental project reveals the distribution of treatment options in the various areas are presented in Fig. 3.3.

3.2.2.1 Details of field layout

Location	- Experimental farm of PFDC, CAE
Season	- Rabi, 2019 - 20
Design	- Split Plot
Replications	- 3
Main plot treatment	- 3
Sub - main plot treatment	- 3
Number of plots	- 27 + 1 (control)

Gross plot size	- 18.4 m × 17 m (main plot)
	- 17 m × 5 m (control plot)
RDF	- 120 kg N: 60 kg P_2O_5: 40 kg K_2O / ha
Crop	- Wheat
Variety	- Rajendra Gehun - 1
Row to row spacing	- 20 cm
Seed Rate	- 100 kg / ha
Date of sowing	- 19. 11. 2019
Date of harvesting	- 28. 3. 2020

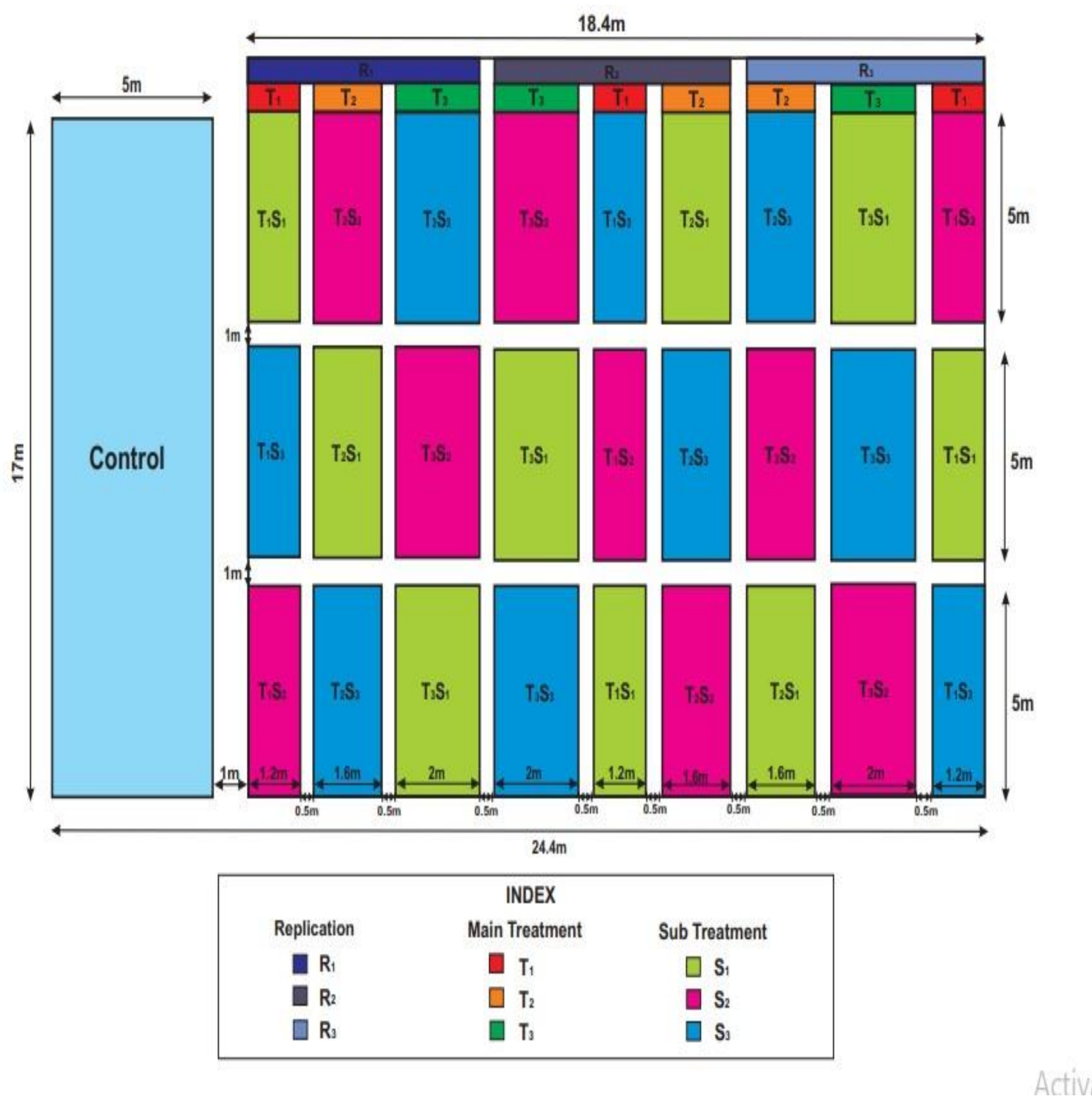

Fig. 3.3: A view of experimental site, RPCAU, Pusa, Samastipur

Fig. 3.4: Drip system installation at field

3.3 Sowing method and seed rate

Wheat was sown after the harvest of previous vegetable crop. One deep ploughing by M. B. Plough and one cross harrowing by disc harrow and one cross ploughing by rotavator followed by levelling were done for land preparation. Treated the seed with Bevistine @ 2.5 g/kg and seeds were uniformly sown in 20 cm apart row @ 100 kg/ha on levelled soil surface and then planking were done in order to cover them.

Fig. 3.5: Sowing of wheat and making bund in the experimental plot

Fig. 3.6 Pipe networks view in experimental plot

3.4 Measurement of irrigation water for border irrigation

The amount of irrigation water by the 7.5 cm throat width of Parshall Flume installed in the field, for recording up stream side of flume H_a of the flow of water were measured. With record flow of water, area of the plot and depth of irrigation, time required to irrigate the plot was calculated by the following formula:

Time required for irrigation (t) in hr = $\frac{100\ (A \times D)}{3.6\ Q}$

Where, A = Area in ha

D = Depth of irrigation water, cm
Q = Discharge, l/s

3.4.1 Weeding

The three-hand weeding was performed by Khurpi after 15, 30 and 45 days of sowing to increase the free standing of the wheat crop during active growth.

3.4.2 Plant preservation measures

No cases of disease and pests occurred during crop duration. However, rodenticide was used to control of rat in field three times.

3.4.3 Harvesting

Harvest the wheat crop with the help of sickles after maturity at 130 days after sowing. Harvested 1 m^2 area of wheat crop as test harvest and removed from the field of each plot as per treatment. Harvested wheat of each plot bundled and tagged. Take five samples of wheat spike also called ear / head and count number of grains (or kernels) of each head. Weight each bundles. On threshing floor, threshed manually each bundle of wheat as per treatment and weight the wheat grains.

3.5 Observation recorded

A. Growth parameters

- Height of plant
- Number of tillers

B. Yield and yield attributes

- Ear length (cm)
- No. of grains / ear
- 1000 - grain weight (g)
- Yield (q/ha)
- Yield of straw (q/ha)
- Biological yield (q/ha)

C. Soil moisture studies

- Water requirement
- Water use efficiency

D. Physical and chemical studies

Collection of soil sample for the determination of initial N, P, K, organic carbon and pH, EC, BD, Field capacity and PWP.

E. Cost economics

1. Cost of cultivation (Rs. /ha)
2. Gross return (Rs. /ha)
3. Net return (Rs. /ha)
4. Benefit: Cost ratio

3.6 Methods used for various studies

Recording the observations on agronomic characters of wheat plant at different stages of growth, representative sample method was adopted. For periodical observations, a sample of five plants in each sub - plot was randomly selected and tagged from sample rows.

3.6.1 After harvesting studies

3.6.1.1 Earhead length (cm)

The length of the ten randomly selected characters (panicles) of the sample plants was measured in the laboratory. The panicle length was studied from the bottom of the panicle to the top of the panicle and the length at which the panicles were calculated.

3.6.1.2 1000 - grain weight

A thousand representative samples of grain were taken from the grain harvest for each treatment and their weights were recorded in grams, then their normal weight was recorded and recorded.

3.6.1.3 Grain yield (q/ha)

Harvested wheat stalks in each area of the plot was threshed and winnowed separately. After cleaning the grain was dried and the burden turned into recorded and as a result samples have been taken from every sub-plot to determine the moisture content material with the help of a moisture meter. Finally, grain yield changed into calculated at 12 per cent moisture content earlier than the analysis become taken into consideration. Then internet plot yield changed into converted to q / ha.

3.6.1.4 Yield of straw (q/ha)

Threshed wheat, yield of straw was recorded as per plot wise. Then the samples of straw were taken and sun dried. The data thus obtained were used for its dry weight and for statistical analysis of straw yield. Finally, the yield was converted into q/ha.

3.6.1.5 Harvest index (%)

The grains and straw/residue were weighed separately and the yield index was calculated.

$$\text{H. I.} = \frac{\text{Grain yield}}{\text{Grain yield} + \text{Straw yield}} \times 100$$

3.6.2 Soil moisture studies

3.6.2.1 Soil moisture content (%)

Soil samples of soil moisture studies were collected with a sampling auger from a depth of 0 - 30 cm, after which the soil moisture was calculated by the process of determining the soil moisture, in successive soil layers above sowing, before and after other irrigation and finally at harvest. Soil samples were collected from three points within the intellectual examination and treatment facility. Thereafter the combined samples of 50 g to 100 g of soil were placed in moist boxes with a tightly sealed lid. The water samples were quickly weighed, dried at a constant temperature in the oven at 105 ℃ (approximately 24 hours) and empowered after cooling in desiccators. After that weights of moisture boxes were taken.

$$\text{M. C (\%)} = \frac{\text{Wet soil weight} - \text{dry soil weight}}{\text{Weight of dry soil}} \times 100$$

3.6.2.2 Water use efficiency

It can be calculated as the division of crop yield to the total depth of water given in the field inclusive of effective rainfall that has occurred during growing period of crop.

$$\text{WUE (kg/ha - cm)} = \frac{\text{Y} \left(\frac{\text{kg}}{\text{ha}}\right)}{\text{WR (cm)}}$$

Where,

WUE = Water use efficiency (kg/ha - cm)

Y = Grain yield (kg/ha)

WR = Total water requirement (cm)

3.7 Economics of production

The following economic parameters were found based on current output prices and the cost of various inputs during the experiment.

a) Cultivation cost (Rs. /ha)

b) Gross monetary return

c) Net monetary return

d) B: C ratio

CHAPTER - 4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The current study ‘Effect of Dripper Spacing on Yield and Water Productivity of Wheat under Drip Irrigation’ was conducted during the 2019 (Rabi) at Research plot of Precision Farming Development Centre, R P C A U, Pusa, Bihar. The wheat crop was seeded under drip irrigation with three lateral spaces (30 cm, 40 cm and 50 cm) with three dripper/emitter spaces (30 cm, 40 cm and 50 cm) and three times repeated in the design of split plot. Observations on the hydraulic performance of the emitting pipes. Distribution of soil moisture and critical growth and yield were monitored in successive growth stages, later during and after harvesting the product. The details of the year planted for each character were measured and placed in statistical analysis tables.

4.1 Drip system

Prior to application for irrigation of the wheat crop, uniform depth of irrigation was tested using the same irrigation for every treatment. The system testing was done by every dripper discharge in every treatment and in conformity with their mean discharge, the appropriate irrigation time was computed. The mean discharge of all treatment plot shown in Table 4.1 for the trial period.

Table 4.1: Drippers discharge, lph (mean)

Treatment	R_1	R_2	R_3	**Average**
T_1S_1	3.78	3.76	3.68	3.74
T_1S_2	3.84	3.78	3.9	3.84
T_1S_3	3.92	3.96	3.82	3.9
T_2S_1	3.81	3.87	3.96	3.88
T_2S_2	3.91	3.86	3.84	3.87
T_2S_3	3.98	3.88	3.93	3.93
T_3S_1	3.74	3.9	3.91	3.85
T_3S_2	3.87	3.93	3.72	3.84
T_3S_3	3.87	3.87	3.96	3.9

The first depth of irrigation 2.94 mm (Table 4.4) was applied to the crop as per crop water requirement on 10 December 2019 by operating the drip system for required time period shown in Table 4.2, according to that water should be given as per required amount to treatments.

Table 4.2: Time of irrigation application

Treatment	Time of application (min)			Average
	R_1	R_2	R_3	
T_1S_1	3.8	3.8	3.8	3.80
T_1S_2	5.1	5.1	5.1	5.10
T_1S_3	6.1	6.1	6.1	6.10]
T_2S_1	5.1	5.1	5.1	5.10
T_2S_2	6.8	6.8	6.8	6.80
T_2S_3	8.1	8.1	8.1	8.10
T_3S_1	6.4	6.4	6.4	6.40
T_3S_2	8.5	8.5	8.5	8.50
T_3S_3	10.2	10.2	10.2	10.20

The required amount of water i.e. 15, 20 and 31.10 litres were applied to the fields having lateral division 30 cm, 40 cm and 50 cm respectively and shown in the Table 4.3. Per unit area depth of irrigation was 2.94 mm and presented in Table 4.4.

Table 4.3: Water application

Treatment	Total no. of dripper	Volume of water applied (lit)			
		R_1	R_2	R_3	Average
T_1S_1	64	26.1	25.9	26.6	26.0
T_1S_2	48	26.1	25.9	26.0	26.0
T_1S_3	40	26.1	25.9	26.0	26.0
T_2S_1	64	35.7	35.8	35.7	35.7
T_2S_2	48	35.7	35.6	35.7	35.7
T_2S_3	40	35.8	35.6	35.7	35.7
T_3S_1	64	45.5	45.4	45.6	45.5
T_3S_2	48	45.5	45.5	45.5	45.5
T_3S_3	40	45.3	45.6	45.6	45.5

Table 4.4 Depth of water applied

Treatment	Plot area (m^2)	Total depth of water applied (mm)			
		R_1	R_2	R_3	Mean
T_1S_1	8	2.94	2.94	2.94	2.94
T_1S_2	8	2.94	2.94	2.94	2.94
T_1S_3	8	2.94	2.94	2.94	2.94
T_2S_1	10	2.94	2.94	2.94	2.94
T_2S_2	10	2.94	2.94	2.94	2.94
T_2S_3	10	2.94	2.94	2.94	2.94
T_3S_1	6	2.94	2.94	2.94	2.94
T_3S_2	6	2.94	2.94	2.94	2.94
T_3S_3	6	2.94	2.94	2.94	2.94

1.1.2 Hydraulic performance of the system

Drip irrigation system, performance of hydraulic was analysed and then compared to the temporary changes between the various dripper spacing for crop with different parameters of uniformity and shown in Table 4.5

Table 4.5 Variables of uniformity of dissimilar discharge of emitter

Uniformity Parameters	Dripper spacing 30 cm	Dripper spacing 40 cm	Dripper spacing 50 cm
Coefficient of manufacture variation (C_v) in %	1.38	1.43	1.20
Coefficient for Emitter Flow Variation (CEFV)	1.06	1.45	0.75
Emission uniformity (EU)	98.90	98.70	98.80

It can be seen from Table 4.5 that the coefficient of manufacturing variation, coefficient of emitter flow variation, and emission uniformity were remained in excellent during the test setup. The coefficient of manufacturing variation was recorded 40 cm and 50 cm emitter spacing was 1.43 and 1.20 which is maximum and minimum and falls in the best category ie <10%.

4.2 AFTER HARVESTING STUDIES

4.2.1 Effective number of tillers

The experiment gives the result of effective number of tillers from each plot.

Table 4.6: Lateral and dripper spacing effect on number of tillers

Treatment	Effective number of tillers (MRL)
	Rabi-2019
Lateral Spacing (3)	
T_1 - 30 cm	65.3
T_2 - 40 cm	62.5
T_3 - 50 cm	59.0
Mean	**62.26**
Dripper Spacing (3)	
S_1 - 30 cm	67.7
S_2 - 40 cm	64.8
S_3 - 50 cm	64.8
Control	**65.76**

Effect of lateral spacing

Diverse lateral dispersing proven noteworthy impact on effective wide variety of tillers/MRL. In any case, it changed into recorded that wide variety of a success tillers/MRL increments with the decline in lateral dispersing. During cropping season, 30 cm lateral separating recorded basically better quantity of tillers (65.3) trailed via 40cm lateral dividing (62.5) and 50cm lateral dispersing (59.0). 40cm lateral dispersing moreover recorded essentially higher number of viable tillers while contrasted with 50 cm lateral isolating. The percentage lower in compelling tillers while lateral dispersing increments from 30 cm to forty cm, 40 cm to 50 cm and 30 cm to 50 cm by using 43 %, 5.6 % and 9.6 % one by one.

30 cm lateral dividing recorded altogether better range of possible tillers (67.7) trailed via 40 cm lateral dispersing (64.8) and 50 cm lateral isolating. Data likewise exposed that better wide variety of compelling tillers/MRL turned into recorded in all lateral dividing while contrasted with manage., 30 cm, forty cm and 50 cm lateral separating founded 14.2%, 10.4% and 5.1% better wide variety of a hit tillers one by one when contrasted with manipulate (56.0).

Effect of dripper spacing

Diverse dripper isolating indicated huge impact on number of a hit tillers/MRL. Although, it turned into founded that range of powerful tillers increments with diminishing in dripper separating. Throughout the cropping season, 30cm dripper dispersing founded basically better wide variety of successful tillers (64.7) at general with 40cm dripper dividing (69.1) yet fundamentally highest than 50 cm dripper isolating (58.9). 40cm dripper separating moreover founded essentially highest number of productive tillers while contrasted with 50cm dripper dispersing. The percent lower in a hit tillers whilst dripper dividing increments from 30cm to forty cm, 40cm to 50cm and 30cm to 50cm via 2.5 %, 6 % and 9.0 % one after the other.

30cm dripper dividing founded fundamentally higest range of a success tillers (66.4) at general with 40cm dripper dispersing (64.6) still altogether higher than 50cm dripper keeping apart. Information likewise uncovered that better quantity of effective tillers/MRL changed into recorded in all dripper setting apart while contrasted with manage.

4.2.2 LENGTH OF EARHEAD

The results related to earhead length is shown in Table 4.7

Table 4.7: Lateral and dripper spacing effect on grain yield

Treatment	Grain Yield (q ha^{-1})
	Rabi-2019
Lateral Spacing (3)	
T_1 - 30 cm	46.37
T_2 - 40 cm	43.7
T_3 - 50 cm	41.77
Mean	43.95
Dripper Spacing (3)	
S_1 - 30 cm	45.22
S_2 - 40 cm	43.56
S_3 - 50 cm	43.06
Control	39.82

EFFECT OF LATERAL SPACING

Distinctive lateral separating indicated huge impact on length of earhead. Notwithstanding, the result found that the earhead length increments in comparison with decline in lateral separating. 30 cm lateral dispersing founded fundamentally highest earhead lenth (8.24 cm) at standard with 40 cm lateral dividing (8.04 cm) yet altogether better than 50 cm lateral separating (7.63 cm).Earhead length of 40 cm and 50 cm lateral dispersing was measurably at standard. The percent decrease long of earhead when lateral dividing increments from 30 cm to 40 cm, 40 cm to 50 cm and 30 cm to 50 cm by 2.42 %, 5.10 % and 7.40 % separately

30 cm lateral dispersing recorded altogether excessive earhead length (8.28cm) when contrasted with 40 cm lateral dividing (7.91 cm) and 50 cm lateral separating. Information additionally uncovered that decrease long of earhead was recorded in all lateral dispersing when contrasted with control

Effect of dripper spacing

Impact of various dripper/emitter dividing on length of earhead was noticed irelevant. Nonetheless, it was founded that earhead length increments with the decline in dripper dispersing. 30 cm dripper dividing founded most elevated length of the earhead (8.15cm) when contrasted with 40 cm dripper dispersing (7.96 cm) and 50cm dripper separating (7.81cm). Information that decrease in the length of earhead was founded in every dripper separating when contrasted with control.

4.2.3 GRAINS PER EARHEAD

The result obtain to number of grains per earhead is presented in Table 4.8**.**

Table 4.8: Lateral and dripper spacing effect grains per earhead

Treatment	**Grains/ear head**
Lateral Spacing (3)	
T_1 - 30cm	48.7
T_2 - 40cm	46
T_3 - 50cm	43.8
Mean	46.1
Dripper Spacing (3)	

S_1 - 30cm	48
S_2 - 40cm	46
S_3 - 50cm	44.6
Control	52.2

Effect of lateral spacing

Diverse lateral dividing indicated critical impact on grains per earhead. Notwithstanding, it was founded that number of grains per earhead increments with the diminishing in lateral dispersing. 30 cm lateral separating recorded essentially higest no of grains/earhead (48.2) at standard with 40 cm lateral dispersing (45.7) yet altogether better than 50 cm lateral dividing (44.4). The quantity of grain/earhead in 30 cm and 40 cm lateral separating at standard.

Information likewise uncovered that decrease in grains per earhead was founded in every lateral dispersing when contrasted with control. the percent decrease in grains per earhead under 30cm, 40cm and 50cm lateral dispersing when contrasted with control (52.8) were 8.7%, 13.4% and 15.9% individually.

Effect of dripper spacing

Results of various dripper dividing on grains/earhead was founded non-huge in 2019-20. Notwithstanding, from study it is founded that grains/earhead increments with the reduction in dripper separating. 30cm dripper separating founded most noteworthy number of grains/earhead (48.4) when contrasted with 40cm dripper dispersing (45.6) and 50cm dripper dividing (44.4).

Information additionally uncovered that decrease in grains/earhead was fpunded in every dripper/emitter dividing when contrasted with control plot. The percent decrease in grains/earhead under 30 cm, 40 cm and 50 cm dripper separating when contrasted with control (52.8) were 8.3 %, 13.6 % and 15.9 % individually

4.2.4 Biological yield

The results related to biological yield is showed in Table 4.9.

Table 4.9: Lateral and dripper spacing effect on biological yield

Treatment	Biological Yield (q ha^{-1})
Lateral Spacing (3)	
T_1 - 30cm	102.59
T_2 - 40cm	97.17
T_3 - 50cm	92.67
Mean	230.65
Dripper Spacing (3)	
S_1 - 30cm	100.78
S_2 - 40cm	96.73
S_3 - 50cm	94.23
Control	86.25

Effect of lateral spacing

Distinctive lateral separating indicated noteworthy impact on natural yield in rabi 2019-20. In the study the work revealed that biological yield increments with lessening in the lateral dividing.

30 cm lateral dividing recorded essentially more biological yield (102.59 q ha^{-1}) firmly come behind 40cm lateral separating (97.17 q ha^{-1}) yet altogether better than 50 cm lateral dispersing (92.67 q ha^{-1}). Biological yield at 40cm lateral separating was essentially more than 50 cm lateral dividing. The percent decrease in natural yield when lateral dividing increments from 30 cm to 40cm, 40 cm to 50cm and 30 cm to 50 cm by 5.60 %, 4.80 % and 10.70 % separately.

Information likewise uncovered that highest biological yield was founded in every lateral dispersing when contrasted with control. 30 cm, 40 cm and 50 cm lateral dividing founded 18.94 %, 12.31 % and 7.23 % higher natural yield individually when contrasted with control (86.25 qha^{-1}).

Effect of dripper spacing

Result of various dripper dividing on biological yield was founded non-noteworthy. Notwithstanding, it was founded that biological yield increments with lessening in dripper dividing. During study year, 30cm dripper dispersing founded most elevated biological yield

(100.78 q ha^{-1}) when contrasted with 40 cm dripper dividing (96.73 q ha^{-1}) and 50 cm dripper separating (94.23 q ha^{-1}).

30cm, 40cm and 50cm dripper dividing founded 16.80 %, 12.5 % and 9.25 % higher biological yield individually when contrasted with control (86.25 q ha^{-1}).

4.3 GRAIN YIELD

The consequences related to grain yield are showed in Table 4.10.

Table 4.10: Lateral and dripper spacing effect on grain yield

Treatment	Grain Yield (qha^{-1})
Lateral Spacing (3)	
T_1 - 30 cm	46.37
T_2 - 40 cm	43.70
T_3 – 50 cm	41.77
Mean	43.95
Dripper Spacing (3)	
S_1	45.22
S_2	43.56
S_3	43.06
Control	39.82

Effect of lateral spacing

Diverse lateral dispersing demonstrated noteworthy impact on grain yield. From the study the result founded that the grain yield increments with the reduction in lateral dividing. 30 cm lateral dividing recorded fundamentally better return (46.40 qha^{-1}) trailed by 40 cm lateral separating (43.70 qha^{-1}) yet essentially better than 50 cm lateral dispersing (43.43 q ha^{-1}). Further, grain yield founded at 40 cm and 50 cm lateral dispersing was at standard. The percent decrease in grain yield when lateral dispersing increments from 30 cm to 40 cm, 40 cm to 50 cm and 30 cm to 50 cm by 6.17 %, 0.62 % and 6.8 % separately.

Information likewise uncovered that highest grain yield was founded in all lateral dividing when contrasted with control plot. 30 cm, 40 cm and 50 cm lateral dividing founded 20.45 %, 13.44 % and 12.74 % higher grain yield individually when contrasted with control plot (39.05 qha^{-1}).

Effect of dripper spacing

Impact of various dripper separating on grain yield was record non-critical. Notwithstanding, from the result founded that grain yield increments with the abatement in dripper separating. At study year, 30cm dripper separating founded most noteworthy grain yield (44.08 q ha^{-1}) when contrasted with 40cm dripper dispersing (43.06 q ha^{-1}) and 50 cm dripper dividing (42.77 q ha^{-1}).

Information additionally uncovered that highest grain yield was founded in all dripper separating when contrasted with control. 30 cm, 40 cm and 50 cm dripper dispersing founded 12.5 %, 10.4 % and 10.0 % highest grain yield individually when contrasted with control plot (38.52 qha^{-1}).

Table 4.11 Lateral spacing with dripper spacing effect on grain yield

Lateral spacing	Dripper spacing (S)		
	S_1 - 30 cm	S_2 - 40 cm	S_3 - 50 cm
Grain yield (q/ha)			
T_1 – 30 cm	47.16	45.6	46.36
T_2 – 40 cm	45.17	44.36	41.59
T_3 – 50 cm	45.33	40.74	41.24
Control	39.05		

4.3.1 STRAW YIELD

The consequences related to straw yield is showed in Table 4.12.

Fig. 4.12: Lateral and dripper spacing effect on straw yield

Lateral spacing	Dripper spacing		
	S_1 – 30cm	S_2 – 40cm	S_3 – 50cm
Straw yield (q/ha)			
T_1 – 30 cm	58.29	55.89	54.47
T_2- 40 cm	54.46	53.84	52.10
T_3- 50 cm	51.93	49.78	49.01
Control	47.20		

Effect of lateral spacing

Diverse lateral dividing indicated noteworthy impact on straw yield in rabi 2019-20. Notwithstanding, from result founded that straw yield increments with the lessening in lateral dividing. 30cm lateral dispersing founded altogether highest straw yield (54.45 qha^{-1}) firmly come behind 40cm lateral separating (52.08 q ha^{-1}) yet fundamentally better than 50 cm lateral dividing (48.78 q ha^{-1}). Further, 40cm lateral separating likewise founded essentially higher straw yield when contrasted with 50 cm lateral dispersing. The percent decrease in straw yield when lateral separating increments from 30cm to 40cm, 40 cm to 50 cm and 30 cm to 50cm by 4.5 %, 6.2 % and 10.4 % separately.

Information likewise uncovered that higher straw yield was founded in every lateral dividing when contrasted with control. 30 cm, 40 cm and 50 cm lateral separating founded 16.7 %, 13.1 % and 7.3 % more straw yield individually when contrasted with control (45.22 qha^{-1}).

Effect of dripper spacing

Result of various dripper separating on straw yield was found non-critical, yet discovered noteworthy. From the result founded that straw yield increments with the abatement in dripper separating. In the study year, 30cm dripper dispersing founded most elevated straw yield (53.06 qha^{-1}) when contrasted with 40cm dripper dividing (51.15 q ha^{-1}) and 50 cm dripper separating (51.10 q ha^{-1}).

Information likewise uncovered that highest straw yield was founded in all dripper separating when contrasted with control. 30cm, 40cm and 50cm dripper dispersing founded 14.8 %, 11.6 % and 11.5 % more straw yield individually when contrasted with control plot (45.22 q ha^{-1}).

4.3.2 Test weight (1000 grain wt.)

The consequences related to test weight is given in Table 4.13.

Table 4.13: Lateral and dripper spacing effect on test weight

Treatment	Test weight (gm)
Lateral spacing (3)	
T_1 – 30 cm	42.17
T_2– 40 cm	41.51
T_3– 50 cm	40.26
Mean	41.31
Dripper spacing (3)	
S_1 – 30 cm	41.74
S_2 – 40 cm	41.29
S_3 – 50 cm	40.92
Control	38.6

Effect of lateral spacing

Distinctive lateral dividing indicated huge impact on test weight. Test weight increments with the abatement in lateral dividing. 30 cm lateral dividing founded essentially highest test weight (42.14 gm) at standard with 40cm lateral separating (41.86 gm) yet altogether better than 50 cm parallel dispersing (40.19 gm). Further, distinction in test weight at 40cm and 50cm lateral dispersing was likewise huge. The percent decrease in test weight when lateral separating increments from 30cm to 40cm, 40cm to 50cm and 30cm to 50cm were 0.66 %, 3.98 % and 4.62 % individually.

Information likewise uncovered that highest test weight was founded in every lateral separating when contrasted with control. Highest test weight was founded in 30 cm, 40 cm and 50 cm lateral dispersing by 10.5 %, 9.9 % and 6.2 % separately when contrasted with control (37.7 gm).

Effect of dripper spacing

Impact of various dripper dispersing on test weight was record non-huge. Anyway the study disclosed that test weight increments with the reduction in dripper dispersing.in the study year, 30cm drippers dispersing recorded most elevated test weight (41.57 gm) firmly come after 40cm dripper dividing (41.54 gm) and 50cm dripper separating (41.07 gm).

Information additionally uncovered that highest test weight was founded in all dripper dividing when contrasted with control. Granular seeds were founded by 9.3 %, 9.2 % and 8.2 % expansion in test weight under 30cm, 40cm and 50cm dripper dispersing separately when contrasted with control (37.7 gm).

4.3.3 Harvest index

The results related to harvest index is showed in Table 4.14.

Table 4.14: Effect of lateral and dripper spacing on harvest index

Treatment	**Harvest index (%)**
Lateral spacing (3)	
T_1 – **30 cm**	45.1
T_2 – **40 cm**	44.91
T_3 – **50 cm**	44.89
Mean	44.97
Dripper spacing (3)	
S_1 – **30 cm**	45.07
S_2 – **40 cm**	45.05
S_3 – **50 cm**	44.79
Control	**45.77**

Distinct lateral and dripper spacing appear irrelevant result for harvest index. Harvest index rise with the reduce in lateral and dripper spacing.

4.4 WATER PRODUCTIVITY

The results related to water productivity are showed in Table 4.15**.**

Table 4.15: Lateral and dripper spacing effect on water productivity

Treatment	**Water Productivity (Kg/m^3)**
Lateral spacing	
T_1– 30 cm	1.08
T_2– 40 cm	1.01
T_3– 50 cm	0.97
Mean	1.02
Dripper spacing	
S_1– 30 cm	1.08
S_2– 40 cm	1.01
S_3– 50 cm	0.97
Control	0.74

Effect of lateral spacing

Distinctive lateral separating demonstrated critical impact on water efficiency. In any case, it was founded that water efficiency increments with the decline in lateral dividing. During study year, 30cm lateral separating founded altogether highest water efficiency (1.04 Kg/m^3) when contrasted with 40cm lateral dividing (0.99 Kg/m^3) and 50 cm lateral dispersing (0.95 Kg/m^3). Further, water efficiency at 40 cm and 50cm lateral dividing was at standard. The percent decrease in water efficiency when lateral separating increments from 30 cm to 40 cm, 40 cm to 50 cm and 30 cm to 50 cm were 5.0 %, 3.0 % and 9.0 % individually.

Information additionally uncovered that highest water efficiency was founded under all lateral dividing when contrasted with control. The percent expanded in water efficiency in 30 cm, 40 cm and 50 cm lateral dividing were 32.7%, 29.3% and 26.3% individually when contrasted with control (0.70 Kg/m^3).

Effect of dripper spacing

Impact of various dripper separating on water efficiency was non-huge. In any case, it was founded that water efficiency increments with the diminishing in dripper separating. During study year, 30 cm dripper dispersing founded most elevated water efficiency (1.01 Kg/m^3) when contrasted with 40 cm dripper dividing (0.99 Kg/m3) and 50 cm dripper separating (0.98 Kg/m^3).

Information likewise uncovered that highest water profitability was recorded under all dripper separating when contrasted with control. The percent expansion in water efficiency under 30 cm, 40 cm and 50 cm dripper dispersing was 30.7 %, 29.3 % and 28.6 % individually when contrasted with control (0.70 Kg/m^3).

4.5 WATER STORAGE EFFICIENCY

The results related to water productivity is showed in Table 4.16.

Table 4.16: Lateral and dripper spacing effect on water storage efficiency

Treatment	Water storage efficiency (%)
	Rabi-2019
Lateral spacing (3)	
T_1– 30 cm	87.89
T_2– 40 cm	79.83
T_3– 50 cm	72.11
Mean	79.94
Dripper spacing (3)	
S_1– 30 cm	83.56
S_2– 40 cm	80.22
S_3– 50 cm	76.06
Control	68.5

Effect of lateral spacing

The study revealed that water stockpiling productivity increments with the diminishing in lateral dividing. 30 cm lateral dividing founded altogether higher water stockpiling proficiency (91.00 %) when contrasted with 40cm lateral dispersing (80.22 %) and 50 cm lateral separating (73.56 %). 40 cm lateral dispersing likewise recorded fundamentally higher water stockpiling productivity when contrasted with 50 cm lateral separating. The decrease in water stockpiling effectiveness when lateral separating increments from 30 cm to 40 cm, 40 cm to 50 cm and 30 cm to 50 cm were 10.78 %, 6.66 % and 17.44 % individually.

Information likewise uncovered that highest water stockpiling productivity under each lateral separating was founded when contrasted with control. The increment in water stockpiling productivity under 30cm, 40cm and 50cm lateral separating were 20.0 %, 9.22 % and 2.56 % individually was founded when contrasted with water stockpiling effectiveness of control (71.0 %).

Effect of dripper spacing

Distinctive dripper separating demonstrated huge impact on water stockpiling productivity. The study revealed that water stockpiling proficiency increments with the abatement in dripper separating. In the study year, 30 cm dripper separating founded fundamentally highest water stockpiling productivity (85.11 %) when contrasted with 40 cm dripper dividing (81.78 %) and 50 cm dripper dispersing (77.0 %). Further, 40cm dripper separating likewise founded essentially highest water stockpiling productivity when contrasted with 50cm dripper dispersing. The decrease in water stockpiling effectiveness when dripper separating increments from 30 cm to 40 cm, 40 cm to 50 cm and 30 cm to 50cm were 3.33 %, 4.72 % and 8.05 % separately.

4.6 ECONOMICS OF THE TREATMENT

Economics is the social science that studies how people interact with things of value; in particular, the production distribution, and consumption of goods and services. Economics focuses on the behaviour and interactions of economic agents and how economics work. It is general, social inclination of individual to pick monetary one for continuing their fruitful life alongside his relatives. In agribusiness, it is pre-verified that the appropriation of any new procedure, assortment or any degree of information will rely upon their financial attainability. Accordingly, before making any last suggestion for business development, it is basic to have thought regarding the cost in question, complete out turn and overall gain accomplished, so for, in the current examination has been given in detail.

4.17: Economic analysis of different treatments on rupees per hectare area basis

Treatment	Cultivation cost (Rs. ha-1)			Gross monetary returns (Rs. ha^{-1})			Net monetary return (Rs/ha)	Economic water productivity (Rs/m^3)	Benefit cost ratio
	Wheat cultivation cost	Drip installation cost	Total	Grain	Straw	Total			
T_1S_1	15905	25703	41608	84,888	29,145	114,033	72425	49.33	2.74
T_1S_2	15905	23769	39674	82,080	27,945	110,025	70351	47.92	2.77
T_1S_3	15905	18982	34887	83,448	27,235	110,683	75796	51.63	3.17
T_2S_1	15905	19014	34919	81,306	27,230	108,536	73296	49.92	3.10
T_2S_2	15905	17567	33472	79,848	26,920	106,768	73296	49.92	3.18
T_2S_3	15905	13984	29889	74,862	26,050	100,912	71023	48.38	3.37
T_3S_1	15905	14942	30847	81,594	25,965	107,559	76712	52.25	3.48
T_3S_2	15905	13784	29689	73,332	24,890	98,222	68533	46.68	3.30
T_3S_3	15905	10918	26823	74,232	24,505	98,737	71914	48.98	3.68
Control	15905	4500	20405	61,236	23,600	84836	64431	43.89	4.1

4.6.1 Cultivation cost

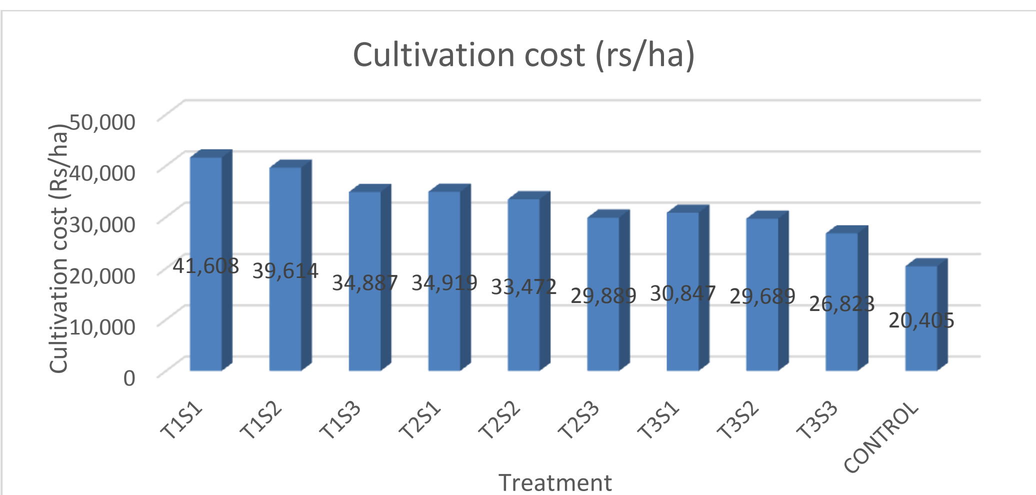

Fig 4.1 Cultivation cost of wheat cultivation in different lateral and dripper spacing

The outcome uncovered that cost of development on highering one hectare of wheat crop under dribble water system need additional venture of least of Rs. 10918 ha^{-1} to limit of Rs. 25703 ha^{-1} . In trickle watered wheat, cost of development discovered greatest (Rs. 41608 ha^{-1}) in 30 cm lateral dispersing (i.e.T_1 S_1) and 30 cm dripper separating and least (Rs. 26823 ha^{-1}) in 50 cm sidelong dividing and 50 cm dripper separating spacing (i.e. T_3 S_3).

4.6.2 Gross monetary returns (GMR)

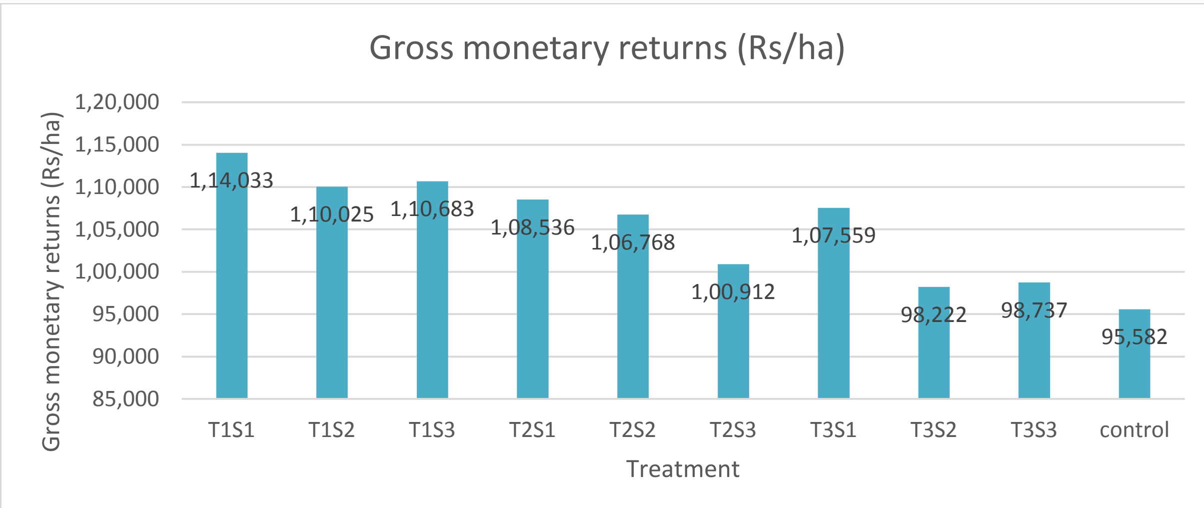

Fig 4.2 Gross monetary returns of wheat cultivation in different lateral and dripper spacing

The gross monetary go back turned into taken as sum overall earnings acquired from the straw and grain yield of wheat as in step with winning marketplace rates i.e. minimal support charge of wheat Rs.1800 in keeping with quintal (average charge of 12 months 2019 - 20) and 500 Rs/quintal for wheat straw.

The value genuinely reveals that there was discount in overall gross earnings with increase in lateral spacing while it accelerated with discernment in dripper spacing. The GMR indicated that impact of various remedy make version on GMR and determined highest of 114033 Rs ha^{-1} in 30 cm lateral spacing and 30 cm dripper spacing (*i.e.*T_1S_1) and lowest of 98222 Rs ha^{-1} in 50 cm lateral spacing and forty cm dripper spacing (*i.e.*T_3S_2). The gross monetary return below supervised pipe irrigation (manage plot) turned into located lowest (95582 Rs ha^{-1}) in comparison to all treatment of drip irrigation.

4.6.3 Net Monetary Return (NMR)

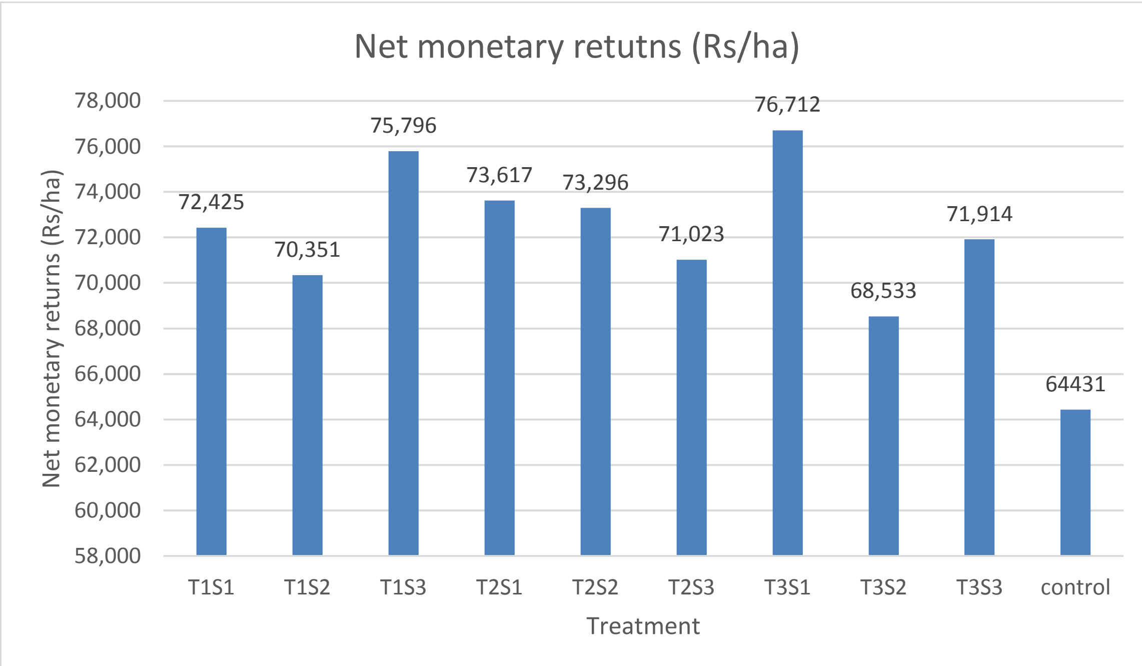

Fig 4.3 Lateral and dripper spacing effect on net monetary return

The Net financial return is the central issue which accommodate the monetary fluctuation of medicines. The net benefit for various medicines was turned out to be by taking away the complete expense of development from the all-out gross salary got from various medicines.

In the consolidated impact of sidelong dispersing and dripper separating, the most extreme net financial returns of 76,712 $\mathrm{Rs.\,ha^{-1}}$ was recorded from the harvest planted under 50 cm lateral dividing with 30 cm dripper dispersing. While, least net financial return of 71,023 $\mathrm{Rs.\,ha^{-1}}$ was recorded from the harvest planted under 40cm lateral dispersing with 50 cm dripper separating.

Contrasting the net financial returns and control plot (directed line water system), it uncovered that money related returns is diminished under all dribble water system treatment when contrasted with financial returns in administered pipe inundated harvest (64.431 $\mathrm{Rs.\,ha^{-1}}$).

4.6.4 Economic water productivity

Information obviously demonstrates that practical efficiency was impacted by various lateral and dripper separating. The conservative water profitability was discovered limit of 52.25 Rs/m^3 in 50 cm parallel dividing with 30 cm dripper dispersing and discovered least of 46.68 Rs/m^3 in 50 cm lateral separating with 40 cm dripper dividing.

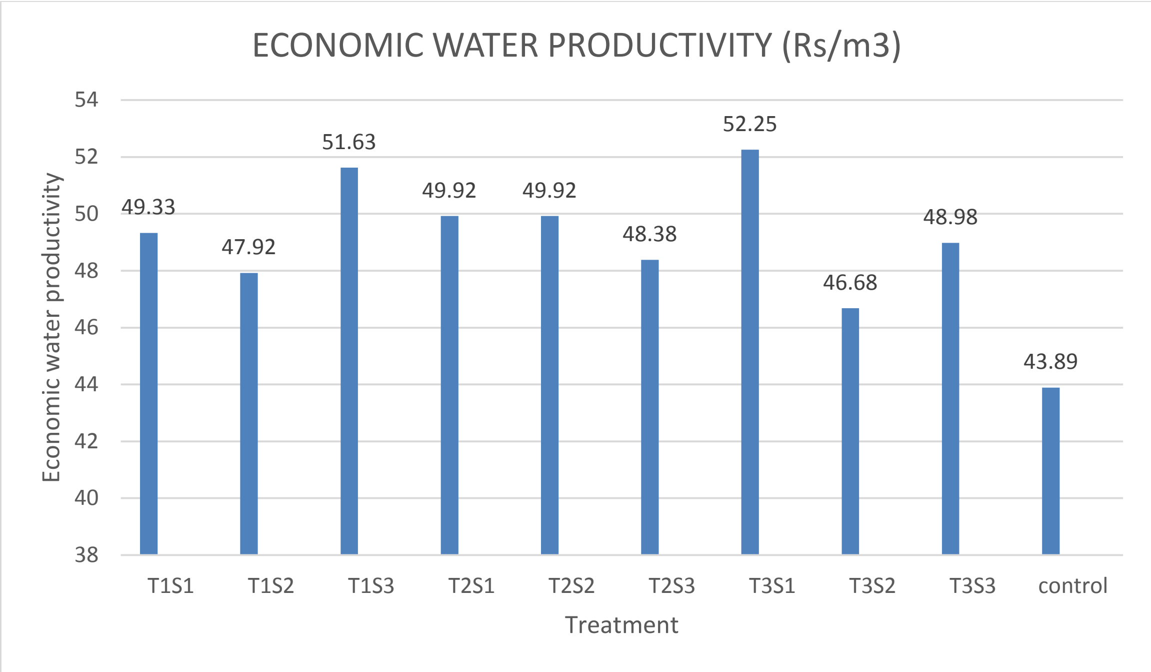

Fig 4.4 Economic water productivity of wheat under different lateral and dripper spacing

Decrease in given water to the crop with increment in yield by ideal water application with dribble water system increments monetary water profitability under all trickle water system treatment as contrast with directed line water system 43.89 Rs/m^3.

4.7 Benefit cost ratio

Benefit cost ratio (BCR), also referred to as Benefit-to-Cost Ratio is the indicator that is typically used within a cost benefit analysis.

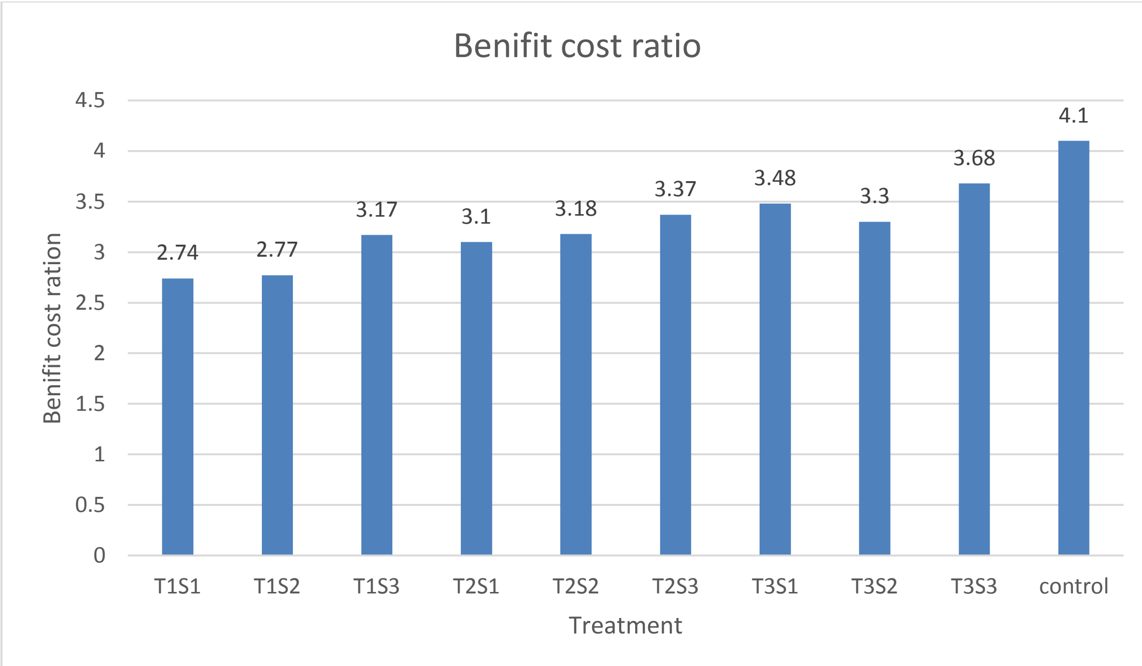

Fig 4.5 Benefit cost ratio of wheat cultivation in different lateral and dripper spacing

The benefit-to-cost proportion is affected by various sidelong and dripper dividing and it increments with increment in parallel dispersing and dripper separating. The benefit cost proportion was discovered limit of 3.68 in 50 cm lateral dividing with 50 cm dripper dispersing and discovered least of 2.74 in 30 cm lateral separating with 30cm dripper separating. As such, B:C proportion is most elevated in greatest sidelong and dripper dispersing mix and discovered least in least parallel and dripper separating mix.

Contrasting the B: C proportion and control (directed line water system), it decreased under all trickle water system treatment as thought about managed pipe water system (4.10).

CHAPTER - 5

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

Nowadays without water one cannot increase their yields and, subsequently, to provide food to the quickly developing population. According to the International Water Management Institute, farming, this substitute about 70 percent of worldwide water. In endeavours to fix this developing issue, many have attempted to shape more powerful techniques for water the executives.

One such strategy is water system the executives. Water system is a strategy for moving water to crops so as to amplify the measure of harvests created. Huge numbers of the water system frameworks don't utilize the water in the most productive manner. This causes more water pointless to be utilized. Consequently, utilization of water system water ought to be finished by the measure of water required by the yields. Legitimate administration ought to be received to maintain a strategic distance from the wastage of water in water system.

One of the interest the board techniques acquainted as of late with control water utilization in Indian farming is miniature water system (MI), which incorporates principally dribble and sprinkler water system strategy. Among all the water system framework, dribble water system framework that can possibly spare water and supplements by permitting water to trickle gradually to the underlying foundations of plants, either from over the dirt surface or covered underneath the surface. The objective is to put water legitimately into the root zone and limit dissipation. It likewise improves profitability and nature of the produce in any event, using the low quality waters. It is generally appropriate for line crops (vegetables, delicate natural products), trees and plant crops where at least one producer can be given.

Consequently, this examination has the need on accentuating and depiction of the building structure measures to assess and decide the recommended elective water system framework and procedure and their impact on crop yields just as plausibility of improving water use proficiency of crop under sandy topsoil soils of Indian horticulture.

The site work was led at the trial homestead of PFDC, College of Agriculture Engineering, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar to consider the impact of dripper dividing on yield and water profitability of wheat crop. To accomplish the destinations of this examination, wheat (Rajendra Genhu - 1) was trimmed with in three lateral spacing i.e. T_1- 30 cm , T_2- 40 cm, T_3- 50 cm and three dripper spacing are S_1 - 30 cm, S_2 - 40 cm and S_3 - 50 cm three repetition receiving a split plot structure. The dirt of exploratory plot is sandy soil in surface, with sand, sediment and earth extent as 46.85, 41.35 and 11.80 percent individually. It was less in natural carbon and phosphorus, though Nitrogen and Potash is at medium level and pH of soil is around of 8.4. The mass thickness of the dirt is 1.46 g/cc, soil profundity is 120 cm. Field limit is 23.50 per cent and perpetual shrivelling point is 8.20 per cent. The trial crop won ideal climate conditions in the editing year of experimentation. The harvest was treated with suggested manure portion 120:60:40 of N: P: K, as basal portion 18:60:40 of N:P:K was applied at the hour of planting and remaining N was provided in three equivalent portion following 25, 50, 75 days from planting.

The harvest was flooded in substitute third day through a surface dribble water system framework. The size of sidelong, sub fundamental and primary line were 16 mm, 63 mm and 75 mm separately and inline dripper of four lph release at one bar working weight was utilized to flood wheat crop. All other agronomic practices were adjusted according to ordinary proposals.

The perceptions on significant development characters, yield properties, yield and pressure driven execution of dribble water system framework were recorded in the trimming year and in this manner the information gathered so for, found the middle value of and classified for factual investigation. The outcomes have been depicted and examined in past part. The remarkable consequences of present examination on water powered execution of dribble water system framework, distinctive development boundary, yield properties and yield are summed up here under:

Hydraulic performance of drip irrigation system

The pressure driven execution of dribble water system has been found between magnificent to great, as uncovered by the different consistency boundaries. The Coefficient of assembling variety (C_v) were between 1.2 % to 1.43 % in treatment and fall in grouping of good classification (< 10%).

The discharge consistency (EUf) just as Statistical coefficient of consistency (SCU) is found in Excellent classification (>90%) (Meriam and Keller, 1978), as they came about worth is over 98% in every one of the three drippers. The Christiansen's Uniformity Coefficient (CUC) from the watched release esteems in the trial framework stayed 100 %. It could likewise be seen that the boundaries of consistency assessed utilizing various methodologies have followed comparative patterns. Close to close estimations of the CCU and SCU uncovered that the release esteems are regularly dispersed and the comparable consistency coefficient processed from the CEFV is advocated.

Soil moisture distribution

The mean and middle of soil dampness content in 0 - 60 cm profundity of soil step by step diminishes with increment of both lateral separating and dripper dividing and recorded most elevated mean estimation of 21.14 % in T_1S_1 and least 17.85 % in T_3S_3. The most extreme (26.47 %) and least (12.08 %) estimation of dampness content was recorded in T_3S_3 showed high dampness variety though least dampness variety is recorded in T_1S_3.

Growth parameters

There is no huge distinction in plant tallness under all medicines and at all the basic stages for example crown root inception (CRI), late turners (LT), late jointing (LJ), blooming (F), draining (M) and at batter (D). In any case, it was discovered that plant tallness in all basic steps increments with the diminishing in sidelong and dripper dividing. 30cm sidelong separating and 30cm dripper dividing *(i.e.* T_1S_1) recorded taller plant stature and most minimal plant tallness was founded under 50cm lateral dispersing and 50 cm dripper dividing (for example T_3S_3) in all the basic phases of plant. Highest plant tallness in directed line water system (control) was founded in vegetative stage for example from CRI stage to late jointing stage and in the regenerative stage, highest plant stature in regulated line water system when contrasted with 50 cm lateral dispersing and 30 cm and 40cm dripper dividing was founded where it was discovered lower when contrasted with 30 cm and 40cm lateral separating and 50 cm dripper dispersing.

The quantity of turners/MRL does not affected because of various medicines in the vegetative stage for example from CRI to late jointing however affected altogether by various lateral and dripper dispersing at conceptive stage. 30cm lateral separating and 30 cm dripper dispersing (for example *(T_1S_1)* recorded altogether highest number of turners among each treatment at regenerative period of plant development. The quantity of turners/MRL in regulated line water system was discovered higher when contrasted with all medicines at CRI stage and after that from late turners to mixture stage, it discovered lower when contrasted with all treatment.

Yield attributes

The yield crediting character viz, compelling number of turners/MRL, length of earhead and number of grains per earhead were altogether influenced by various lateral dividing. 30 cm sidelong dispersing founded fundamentally highest estimation of yield credits when contrasted with 40cm and 50cm lateral dividing. The distinction in yield ascribing character was found non-critical under all dripper separating. Nonetheless, estimation of yield ascribing characters was expanded with diminished in the dripper dispersing. Among each dripper dividing, 30cm dripper dispersing founded highest compelling number of turners/MRL, length of earhead and number of grains per earhead as contrast with 40 cm and 50 cm lateral separating.

In the regulated line water system (control), lower number of powerful turners was founded when contrasted with all medicines for example every lateral and dripper separating while highest length of earhead and number of grains per earhead was founded as contrast with all medicines.

Distinctive treatment demonstrated noteworthy impact on test weight (1000 grain weight). The test weight increments with the lessening in lateral and dripper separating. 30 cm lateral dispersing and 30 cm dripper dividing founded fundamentally highest test weight at standard with 40 cm lateral separating and 40 cm dripper separating yet altogether better than 50 cm lateral dispersing and 50 cm dripper dispersing. Highest test weight was founded in all medicines when contrasted with regulated line water system

Grain and straw yield

Grain and straw yield were altogether affected by various lateral dividing. Among every lateral dispersing, 30 cm lateral dividing founded highest grain and straw yield which thus was better than 40 cm and 50 cm lateral separating. Diverse dripper separating demonstrated no critical impact on grain yield except for noteworthy on straw yield. 30 cm dripper separating founded most elevated grain and straw yield as contrast with 40 cm and 50 m dripper dividing.

Highest grain yield was founded in every lateral and dripper separating when contrasted with regulated line water system (control). 30 cm, 40 cm and 50 cm lateral separating founded 14.0

%, 8.9 % and 4.7 % higher grain yield separately and also 30 cm, 40 cm and 50 cm dripper dividing recorded 11.9%, 8.6% and 7.4% highest grain yield individually when contrasted with control.

Harvest index

Distinctive lateral and dripper separating demonstrated no huge impact on harvest index in any case, harvest index increments with the diminishing in lateral and dripper dividing and highest estimation of harvest index was founded in regulated line water system (control) when contrasted with all treatments.

Water productivity

Water efficiency was fundamentally impacted by various horizontal separating. 30 cm lateral dividing recorded altogether higher water efficiency when contrasted with 40 cm and 50 cm lateral dispersing. The water efficiency under 40 cm and 50 cm lateral separating was at standard. Impact of various dripper separating on water profitability was non-huge. Notwithstanding, it was founded that water efficiency increments with the lessening in dripper separating. 30cm dripper dispersing founded most elevated water efficiency when contrasted with 40cm dripper dividing and 50cm dripper separating.

Highest water efficiency was founded under every lateral and dripper dispersing when contrasted with regulated line water system (control). The percent expansion in water profitability in 30cm, 40cm and 50cm lateral dividing were 31.5 %, 26.7 % and 23.7 % separately when contrasted with control and the percent expansion in water efficiency under 30 cm, 40 cm and 50 cm dripper dispersing was 29.5 %, 26.7 % and 26.0 % individually when contrasted with control.

Sparing of 25.62 % water system water in season 2019-2020 was accomplished under trickle water system when contrasted with regulated line water system. A base increment of grain yield of 2.98 q/ha to a most extreme increment of 6.74 q/ha was founded which was 7.2 % to 14.9 % during season 2019 - 2020. So also, a base increment of grain yield of 0.92 q/ha to a most extreme increment of 6.36 q/ha was founded which was 2.1 % to 13.4 % during season 2019-2020, by means of various treatment mix.

Water storage efficiency

Distinctive lateral separating and dripper dividing indicated noteworthy impact on water stockpiling effectiveness. 30 cm lateral separating recorded altogether higher water stockpiling productivity when contrasted with 40cm lateral dispersing fallowed by 50 cm lateral dividing. Among every dripper separating, 30 cm dripper dividing founded altogether highest water stockpiling productivity when contrasted with 40 m dripper dispersing followed by 50 cm dripper dividing.

Highest water stockpiling productivity under every treatment of trickle water system was founded when contrasted with administered pipe water system (control). The increase in water stockpiling proficiency under 30 cm, 40 cm and 50 cm lateral separating was of greatness of 19.39 %, 11.33 % and 3.61 % individually. The increase in water stockpiling effectiveness under 30 cm, 40 cm and 50 cm dripper dispersing was of size of 15.06 %, 11.72 % and 7.56 % individually when contrasted with water stockpiling productivity of control.

Economics

The most extreme net financial returns of 76712 $\mathrm{Rs\,ha^{-1}}$) was founded from the yield planted under 50 cm lateral dispersing with 30 cm dripper dividing (i.e. T_3S_1,). Though, least net money related return of 68533 $\mathrm{Rs\,ha^{-1}}$) was recorded from the harvest planted under 50 cm lateral dispersing with 40cm dripper separating for example (i.e. T_3S_2,).

Highest financial water efficiency was founded under every medicines of dribble water system when contrasted with managed pipe water system (52.25 $\mathrm{Rs/m^3}$) fundamentally because of 23 % decrease in spread water to the harvest under trickle water system with increment in yield by 2.31 % to 18.43 %.

The advantage cost proportion was impacted by various lateral and dripper dispersing and it was expanded with increment in lateral separating and dripper dividing. (i.e. $\mathrm{T_3S_3}$,). The regulated line water system was discovered more gainful with most noteworthy net money related return of 64431 $\mathrm{Rs\,ha^{-1}}$) and furthermore have a most noteworthy advantage cost proportion of 4.1 when contrasted with all treatment of trickle water system.

Conclusions

Based on exploratory discoveries and conversation on current examination given ends are concluded:

1. Mean grain yield for each of the three dripper dispersing (30, 40, 50 cm) at lateral spacing of 30cm delivers altogether highest wheat yield (47.16 qha^{-1}) trailed by 40cm lateral dividing (45.17 qha^{-1}) and 50cm lateral dividing (45.33 qha^{-1}).

2. Mean wheat yield as founded in all lateral dispersing (30, 40, 50cm) was greatest with 30cm dripper dividing (47.16 qha^{-1}) firmly come after by 40cm dripper separating (45.60 qha^{-1}) and 50cm dripper dispersing (46.36 q ha^{-1}).

3. The lateral dispersing of 30 cm with drippers at 30 cm span came about most elevated grain yield of 47.16 qha^{-1} which is 15 % higher when contrasted with administered pipe water system. It likewise spares 23.99 % water applied and in this manner improve water profitability by 1.06 %.

5. The maximum water productivity was found in 30 cm lateral and dripper spacing as 1.08 Kg/m^3 and minimum water productivity was found in 50 cm lateral and 50cm dripper spacing as 0.97 Kg/m^3. The water productivity found in control plot was 0.74 Kg/m^3 which is 45.94 % less than the maximum water productivity found in drip irrigated wheat crop.

6. The maximum economic water productivity was obtained in 50 cm dripper spacing and 30cm dripper spacing as 52.25 Rs/m^3. 50cm lateral spacing and 40 cm dripper spacing obtained minimum economic water productivity as 46.68 Rs/m^3. Control plot economic water productivity (i.e. 43.89 Rs/m^3) was 19.04 % less than the drip irrigated water productivity.

4. Based on monetary examination, wheat developed under 50 cm lateral separating with dripper at 30 cm span came about the most noteworthy net benefit of Rs.76712 per hectare with greatest financial water efficiency of 52.25 Rs/m^3 of water utilized.

7. In view of present investigation with all factual examination and practical increase, 50cm lateral dividing with 30cm dripper separating might be suggested for wheat crop which may bring about 45.33 q ha^{-1} of wheat with utilization of water up to 32.3cm. The yield acquired in directed line water system was 34.02 q ha^{-1} with water utilization of 43.0 cm. Along these lines dribble water system as suggested may improve yield by 7.34 % and spare water by 23.99 %.

CHAPTER - 6

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CHAPTER - 7

APPENDICES

APPENDIX - A

Meteorological information of Pusa, Samastipur (monthly - wise) during the crop season

2019 - 2020	Temperature ℃		Relative humidity %		Sun shine hours	Rainfall (mm)	No. of rainy days	Wind velocity (Km/hr)	Pan evaporation (mm)
	Max.	Min.	Mor.	Eve.					
19 - 30 Nov.	27.86	13.65	92.58	65.58	3.34	0.0	0	0.75	3.34
1 - 31 Dec.	21	9.7	92	75	2.6	22.0	2	0.2	2,6
1 - 31 Jan.	19.6	9.4	75	75	3.1	6.2	2	-	1.0
1 - 29 Feb.	24.6	92	64	64	8	24	1	-	1.7
1 - 28 Mar.	29	86	57	57	8.3	29.6	4	-	2.1
Total						81.8	9		

APPENDIX - B

Meteorological information of PUSA, Samastipur (daily) for the month of November, 2019

Date	Temperature (^0C)		Relative humidity (%)		Wind speed (Km/hr.)	Rainfall (mm)	Evaporation (mm)	Bright sunshine (hr.)
	Max	Min	Morning	Evening				
1 Nov.	28.5	20.2	95	88	0.5	0.0	3.0	1.5
2 Nov.	28.8	20.5	95	89	0.4	0.0	2.8	1.0
3 Nov.	29.5	20.0	90	80	0.4	0.0	2.4	3.2
4 Nov.	29.8	19.2	95	74	0.4	0.0	2.6	6.0
5 Nov.	28.7	18.8	95	86	0.6	0.0	2.4	4.1
6 Nov.	30.0	19.0	95	58	2.2	0.0	2.0	8.0
7 Nov.	29.8	18.8	94	72	0.9	0.0	2.8	6.2
8 Nov.	29.8	19.0	95	68	0.6	0.0	3.0	5.3
9 Nov.	28.5	19.5	88	58	1.8	0.0	2.6	1.1
10 Nov.	27.2	20.1	87	47	0.5	0.0	2.0	9.2
11 Nov.	25.7	19.5	95	57	1.3	0.0	2.2	8.3
12 Nov.	25.5	18.2	95	44	1.8	0.0	1.8	7.2
13 Nov.	27.0	17.3	92	64	1.6	0.0	2.0	6.5
14 Nov.	28.3	15.5	95	66	0.3	0.0	3.0	3.4
15 Nov.	30.5	16.8	96	85	0.3	0.0	4.0	7.0
16 Nov.	30.1	17.6	89	87	1.6	0.0	1.4	7.3
17 Nov.	29.9	16.2	91	58	1.3	0.0	1.0	6.2
18 Nov.	29.0	16.8	95	60	1.8	0.0	1.0	7.2
19 Nov.	28.8	14.5	93	58	1.8	0.0	1.4	5.1
20 Nov.	28.5	14.0	93	60	2.0	0.0	1.0	5.4
21 Nov.	28.9	13.4	90	58	0.7	0.0	2.2	5.2
22 Nov.	27.4	13.6	97	93	0.2	0.0	1.0	4.5
23 Nov.	27.5	13.3	81	78	0.5	0.0	1.4	4.1
24 Nov.	27.1	13.0	94	54	0.7	0.0	1.2	3.3
25 Nov.	25.5	12.5	91	52	1.0	0.0	1.2	2.3
26 Nov.	27.6	12.0	93	62	1.0	0.0	1.3	1.0
27 Nov.	28.0	12.5	94	80	0.8	0.0	1.4	0.0
28 Nov.	27.4	15.4	95	69	0.3	0.0	1.0	7.5
29 Nov.	29.2	15.0	95	63	0.0	0.0	1.2	0.5
30 Nov.	28.5	14.6	95	60	0.1	0.0	1.0	1.2
Mean/Total*	**28.4**	**16.6**	**93**	**68**	**0.9**	**0.0***	**1.9**	**4.6**

Meteorological information of PUSA, Samastipur (daily) for the month of December, 2019

Date	Temperature (^{0}C)		Relative humidity (%)		Wind speed (Km/hr.)	Rainfall (mm)	Evaporation (mm)	Bright sunshine (hr.)
	Max	Min	Morning	Evening				
1 Dec.	27.4	14.5	93	81	1.0	0.0	1.8	8.0
2 Dec.	26.4	12.3	94	84	1.4	0.0	1.4	5.5
3 Dec.	26.0	12.6	94	81	0.7	0.0	1.4	6.2
4 Dec.	25.0	12.0	96	83	0.7	0.0	1.0	6.5
5 Dec.	24.0	11.3	94	89	0.0	0.0	1.0	7.2
6 Dec.	27.0	11.5	97	63	0.0	0.0	1.4	8.0
7 Dec.	26.7	12.5	94	67	0.0	0.0	1.2	6.3
8 Dec.	24.8	12.0	91	76	0.0	0.0	1.1	4.2
9 Dec.	26.2	12.3	87	53	0.0	0.0	2.0	3.0
10 Dec.	26.4	12.1	92	56	0.0	0.0	0.6	2.3
11 Dec.	25.5	11.5	97	72	0.0	0.0	1.2	0.0
12 Dec.	25.8	12.0	92	77	0.0	0.0	1.0	0.0
13 Dec.	23.5	12.3	93	84	0.0	5.8	0.6	0.0
14 Dec.	23.0	10.7	89	79	0.3	16.2	0.6	3.3
15 Dec.	22.6	9.7	90	83	1.1	0.0	1.0	1.0
16 Dec.	20.5	10.5	92	75	0.0	0.0	1.2	2.3
17 Dec.	22.0	10.9	88	64	0.0	0.0	0.2	3.3
18 Dec.	15.5	9.5	82	77	0.4	0.0	1.6	0.0
19 Dec.	15.5	7.5	93	70	0.0	0.0	0.6	2.5
20 Dec.	17.0	8.2	90	75	0.0	0.0	1.0	0.3
21 Dec.	19.0	8.6	93	76	0.0	0.0	0.8	0.0
22 Dec.	18.9	9.6	94	77	0.0	0.0	0.5	0.0
23 Dec.	18.0	9.5	94	78	0.0	0.0	0.6	0.0
24 Dec.	19.5	6.5	96	63	0.0	0.0	0.8	0.5
25 Dec.	20.0	6.2	93	71	0.0	0.0	1.0	0.0
26 Dec.	13.5	6.4	90	83	0.0	0.0	0.8	0.0
27 Dec.	14.4	6.2	80	74	0.0	0.0	0.4	0.0
28 Dec.	14.5	4.5	97	74	0.0	0.0	0.6	1.2
29 Dec.	14.4	6.5	92	73	0.0	0.0	0.8	2.5
30 Dec.	14.6	6.8	93	72	0.0	0.0	0.8	2.3
31 Dec.	14.6	4.2	95	84	0.0	0.0	1.0	4.5
Mean/Total*	**21.0**	**9.7**	**92**	**75**	**0.2**	**22.0***	**1.0**	**2.6**

Meteorological information of PUSA, Samastipur (daily) for the month of January, 2020

Date	Temperature (^{0}C)		Relative humidity (%)		Wind speed (Km/hr.)	Rainfall (mm)	Evaporation (mm)	Bright sunshine (hr.)
	Max	Min	Morning	Evening				
1 Jan	20.5	6.7	77	69	-	0.0	1.4	1.0
2 Jan	21.0	9.5	86	73	-	0.0	1.5	1.1
3 Jan	20.0	11.0	94	82	-	0.0	1.5	0.0
4 Jan	19.5	10.0	93	83	-	0.0	1.0	0.3
5 Jan	18.4	11.5	92	78	-	0.0	0.6	0.1
6 Jan	17.5	9.0	93	81	-	0.0	0.8	0.0
7 Jan	17.0	7.5	94	75	-	0.0	0.6	3.0
8 Jan	19.0	8.0	94	80	-	0.0	0.6	0.2
9 Jan	19.2	12.5	94	90	-	1.8	0.4	0.0
10 Jan	20.8	12.4	90	83	-	0.0	0.6	1.5
11 Jan	17.4	8.0	92	72	-	0.0	0.4	2.4
12 Jan	15.5	7.5	94	78	-	0.0	1.0	1.0
13 Jan	15.2	6.6	97	78	-	0.0	0.6	0.3
14 Jan	12.5	6.0	96	97	-	0.0	0.6	0.0
15 Jan	19.0	7.5	96	79	-	0.0	0.2	2.5
16 Jan	19.5	9.0	94	73	-	0.0	0.4	6.0
17 Jan	22.8	14.5	81	77	-	0.0	1.1	3.3
18 Jan	23.0	15.0	96	77	-	4.4	2.1	1.0
19 Jan	18.4	13.5	95	76	-	0.0	0.8	0.0
20 Jan	18.5	9.4	96	68	-	0.0	1.2	4.3
21 Jan	18.0	7.5	96	80	-	0.0	1.0	3.0
22 Jan	19.5	8.0	96	62	-	0.0	0.8	6.3
23 Jan	20.5	7.0	89	61	-	0.0	1.4	7.2
24 Jan	21.2	8.0	90	60	-	0.0	1.0	8.5
25 Jan	21.8	6.7	87	58	-	0.0	1.4	8.0
26 Jan	21.6	7.0	90	61	-	0.0	1.6	7.3
27 Jan	20.5	8.2	89	60	-	0.0	1.2	6.4
28 Jan	20.3	8.2	90	70	-	0.0	1.0	4.2
29 Jan	23.0	14.0	89	74	-	0.0	1.2	1.0
30 Jan	23.1	13.0	95	76	-	0.0	1.0	6.5
31 Jan	22.9	10.0	94	79	-	0.0	1.0	9.0
Mean/Total*	**19.6**	**9.4**	**92**	**75**	**-**	**6.2**	**1.0**	3.1

Meteorological information of PUSA, Samastipur (daily) for the month of February, 2020

Date	Temperature (^0C)		Relative humidity (%)		Wind speed (Km/hr.)	Rainfall (mm)	Evaporation (mm)	Bright sunshine (hr.)
	Max	Min	Morning	Evening				
1 Feb	22.0	6.0	97	59	-	0.0	1.4	9.0
2 Feb	22.2	8.3	91	89	-	0.0	2.0	9.3
3 Feb	22.6	7.8	94	49	-	0.0	1.2	9.0
4 Feb	23.4	7.2	90	46	-	0.0	1.6	8.2
5 Feb	22.3	8.0	95	79	-	0.0	1.0	8.0
6 Feb	21.5	9.0	91	56	-	0.0	1.4	7.5
7 Feb	22.5	8.3	76	56	-	0.0	1.8	7.0
8 Feb	23.8	10.1	94	50	-	0.0	2.0	9.4
9 Feb	23.5	9.2	93	46	-	0.0	1.6	8.1
10 Feb	24.5	9.0	74	48	-	0.0	2.2	9.2
11 Feb	24.8	8.2	89	56	-	0.0	2.0	9.3
12 Feb	23.7	8.5	89	83	-	0.0	1.8	9.0
13 Feb	24.0	8.8	90	59	-	0.0	2.4	5.2
14 Feb	25.2	10.0	96	64	-	0.0	1.8	0.3
15 Feb	25.4	13.0	91	67	-	0.0	1.2	7.5
16 Feb	25.3	11.0	91	61	-	0.0	1.6	8.4
17 Feb	25.4	11.5	88	64	-	0.0	1.0	9.1
18 Feb	26.0	13.4	87	48	-	0.0	2.0	9.2
19 Feb	26.3	10.0	95	67	-	0.0	2.4	9.4
20 Feb	25.2	12.0	96	65	-	0.0	1.8	8.0
21 Feb	25.8	14.3	93	72	-	0.0	2.0	8.5
22 Feb	25.9	14.5	96	75	-	0.0	2.2	9.0
23 Feb	26.3	14.2	92	67	-	0.0	1.8	7.5
24 Feb	28.5	15.0	97	69	-	0.0	2.0	6.3
25 Feb	27.2	14.5	92	80	-	24.0	2.4	7.4
26 Feb	24.6	14.5	98	79	-	0.0	0.8	8.2
27 Feb	22.2	13.4	97	76	-	0.0	1.4	8.1
28 Feb	25.2	12.5	98	65	-	0.0	1.6	8.5
29 Feb	26.8	13.1	96	66	-	0.0	2.0	9.0
Mean/Total*	**24.6**	**10.9**	**92**	**64**	**-**	**24.0**	**1.7**	**8.0**

Meteorological information of PUSA, Samastipur (daily) for the month of March, 2020

Date	Temperature (^0C)		Relative humidity (%)		Wind speed (Km/hr.)	Rainfall (mm)	Evaporation (mm)	Bright sunshine (hr.)
	Max	Min	Morning	Evening				
1 Mar	26.6	13.2	95	64	-	0.0	1.8	8.3
2 Mar	28.2	13.3	93	63	-	0.0	2.2	7.0
3 Mar	29.0	15.8	91	55	-	0.0	2.0	8.4
4 Mar	28.5	16.0	94	56	-	0.0	2.4	8.5
5 Mar	27.5	17.5	98	72	-	0.0	1.8	6.3
6 Mar	27.5	16.0	86	66	-	5.6	2.0	9.0
7 Mar	27.4	17.5	90	60	-	2.6	0.6	7.1
8 Mar	26.5	15.0	96	59	-	0.0	0.8	9.0
9 Mar	27.0	15.5	84	74	-	0.0	1.6	10.0
10 Mar	26.8	13.6	88	75	-	0.0	1.2	8.3
11 Mar	27.2	14.6	92	65	-	0.0	2.6	7.3
12 Mar	27.0	16.0	90	60	-	0.0	2.2	8.5
13 Mar	31.5	17.5	91	62	-	0.0	2.4	0.1
14 Mar	24.0	15.5	89	65	-	4.4	0.8	0.0
15 Mar	20.5	14.5	98	64	-	0.0	0.4	7.0
16 Mar	27.4	14.6	96	47	-	0.0	2.2	9.5
17 Mar	28.5	13.5	93	49	-	0.0	3.4	10.4
18 Mar	27.7	15.5	92	55	-	0.0	3.8	10.2
19 Mar	30.0	14.5	90	46	-	0.0	3.4	8.0
20 Mar	31.0	16.0	85	51	-	0.0	3.0	10.1
21 Mar	31.0	17.8	84	59	-	0.0	3.2	6.3
22 Mar	29.8	17.2	92	71	-	0.0	2.6	9.4
23 Mar	29.0	17.0	92	65	-	17.0	2.8	4.0
24 Mar	29.5	17.5	83	62	-	0.0	2.0	10.0
25 Mar	31.6	18.5	84	60	-	0.0	1.8	10.5
26 Mar	33.0	17.7	88	50	-	0.0	2.4	11.2
27 Mar	34.0	18.5	74	40	-	0.0	2.2	11.3
28 Mar	34.0	18.2	76	48	-	0.0	2.0	11.0
29 Mar	32.5	18.0	65	34	-	0.0	2.8	10.4
30 Mar	32.6	17.8	48	35	-	0.0	2.6	10.1
31 Mar	32.5	18.2	55	43	-	0.0	1.6	10.5
Mean/Total*	**29.0**	**16.2**	**86**	**57**	**-**	**29.6**	**2.1**	**8.3**

APPENDIX - C

Cost of cultivation of wheat and drip irrigation Installation cost

Treatment	Cultivation cost (Rs. ha-1)			Gross monetary returns (Rs. ha-1)			Net monetary return (Rs/ha)	Economic water productivity (Rs/m3)	Benefit cost ratio
	Wheat cultivation cost	Drip installation cost	Total	Grain	Straw	Total			
T_1S_1	15905	25703	41608	84,888	29,145	114,033	72425	49.33	2.74
T_1S_2	15905	23769	39674	82,080	27,945	110,025	70351	47.92	2.77
T_1S_3	15905	18982	34887	83,448	27,235	110,683	75796	51.63	3.17
T_2S_1	15905	19014	34919	81,306	27,230	108,536	73296	49.92	3.10
T_2S_2	15905	17567	33472	79,848	26,920	106,768	73296	49.92	3.18
T_2S_3	15905	13984	29889	74,862	26,050	100,912	71023	48.38	3.37
T_3S_1	15905	14942	30847	81,594	25,965	107,559	76712	52.25	3.48
T_3S_2	15905	13784	29689	73,332	24,890	98,222	68533	46.68	3.30
T_3S_3	15905	10918	26823	74,232	24,505	98,737	71914	48.98	3.68
Control	15905	4500	20405	61,236	23,600	84836	64431	43.89	4.1