Original Research Article

Development of Crop Geometry for Drip Irrigated Rice Cultivation

ABSTRACT

Aims: To determine the effectiveness of the selected dripper spacing and dripper discharge rate on crop growth and yield parameters of rice crop and to determine the suitable variety and crop geometry for higher productivity and use efficiency of drip irrigations system.

Study design: Experiment was conducted in strip plot design, method of establishment as main plot treatment viz., Direct seeded under raised bed (M_1) and Transplanting under raised bed, varieties as sub-plot treatment viz., 'ADT 54', 'TKM 13' and 'CR 1009 sub-1'(medium and long duration variety) and spacing as sub- sub-plot treatment viz., 20 x 10 cm , 20 x 20 cm , 25 x 25 cm and 20 x 40 x 10 cm (Paired row) .

Place and duration of the study: Agricultural Engineering College and Research Institute, Kumulur, Tiruchirapalli district of Tamil Nadu during 2019-2021(two years) in sandy clay loam soil during *Samba* season

Methodology: The growth and yield parameters viz., plant height, number of tillers and productivity tillers, number of filled grains, test weight and grain and straw yield was observed and economics on cost of cultivation, gross return, net return and BCR were calculated and water use efficiency and water productivity were calculated.

Results: Studies showed that 90 cm lateral and 60 cm dripper spacing with 4lph is the optimum for rice cultivation under sandy clay loam soil. Combination of direct seeded rice in raised bed with medium duration variety 'TKM 13' in the spacing of 20x40x10 cm(paired row) was recorded higher grain yield(7075 kg/ha) and net return(Rs. 82526/ha), BCR (2.76)and higher water use efficiency (7.69 kg./ha-mm) in drip irrigated paddy cultivation during *Samba* season.

Conclusion: Direct seeding in raised bed with medium duration variety at the spacing of 20x40x10 cm along with other agronomic practices is the best for getting higher yield parameters, yield, net return, higher water use efficiency and water productivity in *Samba (Rabi)* season under drip irrigated rice cultivation.

Key words: *Crop geometry, Drip irrigation, Direct seeded, Water use efficiency and Water productivity.*

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the most important global food crop and grown in at least 114 countries of the world, and more than 50 of them produce equal to or more than 100,000 t. year−1. About 491.4 million tons (mt) of rough rice was produced worldwide from 160.6 million hectares (m ha) of land (1). Decreasing water availability for agriculture threatens the productivity of the irrigated rice ecosystem and ways must be sought to save water and increase the water productivity of rice. The daily consumptive use of rice varies from 6-10 mm and total water ranges from 1100 to 1250 mm depending upon the agro climatic situation, duration of variety, and characteristics of the soils. According to the 2010 UNESCO report, the water footprint (the ratio of total volume of water used to the quantity of production) of India's rice production is 2020 m^3 per tonne, compared to the global average of 1,325 m^3 per tonne. Irrigated rice has very low water use efficiency as it consumes as high as 6667 litters of water to produce one kg (0.15 kg of milled rice / m^3) of rice.

Increasing water shortage and low water productivity in the irrigated dry lands are compelling farmers to adopt resource conservation technologies, such as dry seeded and non-flooded rice. Water productivity can be increased by adopting different water-saving practices such as improved irrigation management (2). Increasing water productivity at the field level can be accomplished by: increasing the yield per unit cumulative ET; reducing unproductive water outflow and depletion (SP, E); or making more effective use of rainfall and adoption of an efficient irrigation system under directed seeded rice (DSR) cultivation. Water use efficiency can be increased by two ways, either by increasing yield or by saving water (3).

To optimize crop production in limited water resource conditions, it is important to understand the relationship between water applied and corresponding yield, yield attributes, and biomass produced. Drip irrigation system for rice cultivation adds cost to production. The cost of a drip irrigation system depends on the number of laterals and the number of drippers/emitters per unit area in addition to the main components. Rice being a closed spaced crop, it requires rupees 1.10 lakhs to 1.25 lakhs per hectare for drip irrigation system. The drip layout is effectively optimized by using the wetting diameter parameter that differs depending on the soil condition as well as the spacing and geometry of the crop. The diameter and depth of wetting are very essential in the design of a drip irrigation system.

Selecting dripper spacing and discharge rate is influenced by crop type, crop root spread and soil type. Many times suboptimal ways of selection of dripper spacing and discharge rate are used. A good drip irrigation system must have a lower investment cost and a higher productivity. The cost of a drip irrigation system may be brought down if the system is designed taking into account the nature of the soil, root spread of the crop. Drip irrigation system applies the water into root zone in frequent low volumes in an attempt to meet the consumptive use of plants with a higher uniformity coefficient than the other irrigation systems.

More information about the agronomic response of rice to drip irrigation is needed to evaluate the technical and economic feasibility of using drip irrigation and the best management practices of rice. With this background this research was conducted to determine the suitable crop geometry to reduce the cost of production and to increase the rice production with higher water productivity.

2. MATERIALS AND METHODS

2.1: Experimental site

The Experiment was conducted at Central Farm (C-block) of Agricultural Engineering College and Research Institute (TNAU), Kumulur, Tamil Nadu (India) during 2019-20 and 2020-2021 in *Samba* season, located at 10°92′North Latitude and 78°82' East Longitude at an elevation of 62 m above the Mean Sea level, average maximum(35.6 °C) and minimum temperature(24.2 °C) during the crop growth period with the mean annual rainfall is 864 mm. Soil texture of the experimental plot was sandy clay loam with the field capacity of 25% and bulk density of 1.63 g/cm^3.

2.2: Experimental Details

Field experiment was conducted to determine the effectiveness of the selected dripper spacing and dripper discharge rate, by preparing main field under two sets of conditions, one in dry condition and another in wet condition, both the conditions, beds and channels (60cmx30 cm) with the height of 25 cm were formed in 50 m length.

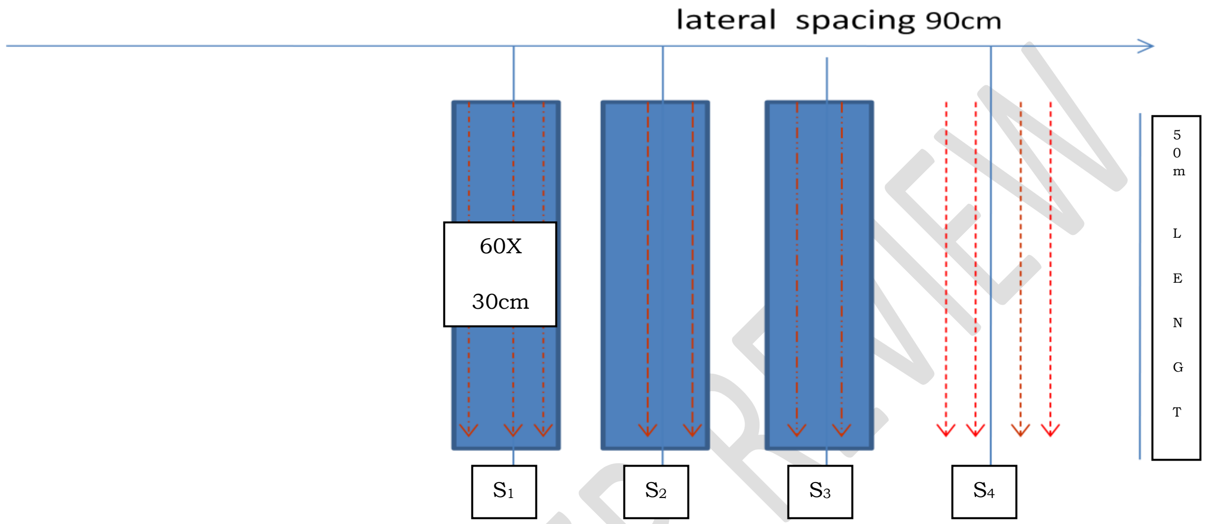

Fig 1: Field layout of drip irrigation system

In dry condition (M_1), treated seeds of three varieties were dibbled in the beds as per the spacing treatments under dry conditions. Pre emergence herbicide of *Pretilachlor* was applied on 3 days after sowing (DAS) in direct sown rice, fertilizer recommendation of 150:60:60 NPK kg/ha, other agronomic practices and pest and disease management were followed; gap filling was done on 12 DAS and maintained with full establishment percentage. Similarly, in wet condition (M_2), 18 days old seedlings produced from SRI nursery technique was planted in beds and channels formed under dry condition and irrigated before transplanting. Fertilizer recommendations of 150:60:60 NPK kg/ha, other agronomic practices, and pest and disease management were followed; gap filling was done on 8 DAT and maintained with full establishment percentage.

In both conditions, drip laterals were laid at a spacing of 90cm with the emitter spacing of 50 cm (4lph) at the centre of the bed and irrigated at 100% PE on alternate days and fertigation was adopted at 100 % RDF of 150:60:60 NPK Kg/ha. Basal dose of phosphorus was applied through super phosphate 375kg/ha and nitrogen and potash was supplied through urea (326 kg) and muriate of potash (100kg) through a drip irrigation system in 6 days. Different levels of NPK quantity was applied based on the stage of the rice crop.

2.3: Experimental design

The objective of the study was to determine the suitability of selected dripper spacing(60 cm) and discharge rate(4lph) on crop growth and yield parameters and to determine the suitable variety and crop geometry for higher productivity and use efficiency in drip irrigation system in paddy during 2019-2021 *Samba* season. Experiments were conducted in strip plot design with following treatments.

Main-plot treatment (Method of establishment):

M_1 - Direct seeded under raised bed

M_2 – Transplanting under raised bed

Sub-plot treatment (Varieties):

V_1 - ADT 54

V_2 - TKM 13

V_3 - CR 1009 sub-1

Sub- sub -plot treatment: (Spacing):

S_1 - 20 x 10 cm (Rectangular) (50 hills/m^2)

S_2 - 20 x 20 cm (Square) (25 hills/ m^2)

S_3 - 25 x 25 cm (Square) (16 hills/ m^2)

S_4 - 20 x 40 x 10 cm (Paired row) (33 hills/ m^2)

2.4: Data collected

2.4.1: Crop growth and yield parameters

The growth parameters viz., plant height and number of tillers, yield parameters viz., productivity tillers, number of filled grains, test weight and grain and straw yield was observed. . The growth and yield parameters of two years field experiments were pooled and the average pooled value is presented in table-1&2.

2.4.2: Economics

Economic analysis on cost of cultivation, gross return, net return and BCR was calculated. Net return value is depicted in Fig 2.

2.4.3: Water use efficiency and water productivity

Irrigation was given @ 100 % Potential Evapotranspiration (PET) on alternate days by using the meteorological data available in AEC&RI, Kumulur and water use efficiency and water productivity was calculated. Total quantity of water applied for direct seeded rice was 920 mm (M_1), and 960 mm for transplanted rice (M_2) and the same quantity was applied irrespective of variety and spacing through a drip irrigation system.

The scheduling of drip irrigation was done based on daily PE values during the crop growth period and the duration of irrigation was computed as follows:

$$\text{Irrigation hours (h)} = \frac{\text{ETc (mm)}}{\text{Application rate (mm h-1)}} \times 100$$

Whereas,

Actual evaporation or crop evapotranspiration (ETc) in mm = ET0 x Crop factor

Reference evaporation or evapotranspiration (ET0) in mm = Previous day evaporation x Pan factor.

Crop factors for paddy at its initial, crop development, reproductive and maturity stages were used were 1.15, 1.23, 1.14, and 1.02 respectively, and a constant pan factor of 0.7 was used.

Water-use efficiency was measured by determining dry weight of grain (yield kg/ha), and dividing that by irrigation plus rainfall(ha.mm).

3. RESULTS AND DISCUSSION

The results revealed that 90 cm lateral and 60 cm dripper spacing with 4lph is the optimum for rice cultivation under sandy clay loam soil.

3.1: Plant growth and yield characters

The result showed that the plant height did not significantly differ with the method of establishment and spacing. However, no difference was observed among varieties, tallest plant at harvest (136cm) was observed in CR 1009 sub 1. Higher number of productive tillers viz., 278, 344 and 314 numbers per square meter was recorded under direct seeded(M_1),TKM 13(V_2), and 20x40x10cm (Paired row)(S_4) as individual treatments compared to transplanted(M_2), other varieties and other spacing treatments(Table 1). Similar trend was also observed in filled grains (32272/m^2, 39416/ m^2,&437444/ m^2), and Grain yield (5.31,5.26&6.22t/ha). Soman et al., 2018 also obtained panicle number, grain number, and test weights (grain) were found to be superior under water and fertilizer management through drip systems(4).

Table 1: Effects of individual treatments on yield parameters

Treatment	Productive tillers (Numbers/m^2)	Filled grains (Numbers/m^2)	Grain yield (t/ha)
Method of establishment			
M_1: Direct seeded	278	32272	5.31
M_2 : Transplanted	238	27525	4.59
Mean	258	29899	4.95
SED	12	964	0.26
CD(p=0.05)	27	1452	0.41
Varieties			
V_1 : ADT 54	253	29078	4.71
V_2 : TKM 13	344	39416	5.26

V_3: CR 1009 sub 1	177	21203	4.88
Mean	258	29899	4.95
SED	9.8	678	0.23
CD(p=0.05)	14	1242	0.38
Spacing			
S_1 : 20 x 10 cm (Rectangular)	275	27184	4.42
S_2 : 20 x 20 cm (Square)	246	30071	4.94
S_3: 25 x 25 cm (Square)	197	24896	4.22
S_4: 20 x 40 x 10 cm (paired row)	314	37444	6.22
Mean	258	29899	4.95
SED	10.4	864	0.14
CD(p=0.05)	19.6	1328	0.31

Combination of direct seeded method (M_1) of establishment with 'TKM 13' (V_2) at a spacing of 20 x 40 x 10 cm (paired row)(S_4) registered a higher number of productive tillers (429 /m^2), filled grains (53196 m^2),grain yield (7.08 t/ha)(Table 2).

Table 2: Effects of combination treatments on yield parameters

Treatments	**Number of productive tillers (Nos./m^2)**	**Number of filled grains (Nos. m^2)**	**Grain yield (t/ha)**
M_1V_1 S_1	300	29400	4.65

$M_1V_1\ S_2$	250	29500	4.78
$M_1V_1\ S_3$	224	27776	4.56
$M_1V_1\ S_4$	363	42108	6.86
$M_1V_2\ S_1$	400	40800	5.39
$M_1V_2\ S_2$	375	45375	6.08
$M_1V_2\ S_3$	256	32768	4.42
$M_1V_2\ S_4$	**429**	**53196**	**7.08**
$M_1V_3\ S_1$	200	18800	4.29
$M_1V_3\ S_2$	150	19800	4.55
$M_1V_3S_3$	160	20480	4.75
$M_1V_3\ S_4$	231	27258	6.30
$M_2V_1\ S_1$	200	20200	3.20
$M_2V_1\ S_2$	200	24400	3.95
$M_2V_1\ S_3$	192	24192	3.97
$M_2V_1\ S_4$	297	35046	5.71
$M_2V_2\ S_1$	350	34300	4.53
$M_2V_2\ S_2$	350	39900	5.35
$M_1V_2\ S_3$	224	26880	3.63
$M_1V_2\ S_4$	363	42108	5.60

M_2V_3 S_1	200	19600	4.47
M_2V_3 S_2	150	21450	4.94
$M_2V_3S_3$	128	17280	4.01
M_2V_3 S_4	198	24948	5.76
Mean	258	29899	4.95
SED	14	988	0.16
CD(p=0.05)	29	1726	0.33

3.2: Economics

Higher Net return of (Rs.51976/ha, Rs.511161/ha and Rs.69959/ha) was recorded under direct seeded (M_1), 'TKM 13' (V_2) and 20x40x10cm (Paired row)(S_4) as individual treatments compared to transplanted(M_2) methods of establishment, other varieties and other spacing treatments. Similar trend was also (2.11, 2.10 &2.46) observed in BCR. Among treatment combinations of method of establishment, variety and spacing, direct seeded at raised bed with TKM 13 at the spacing of 20x40x10 cm was recorded the highest net return of Rs.82526/ha and BCR of 2.76, when compared to other treatment combinations(Fig 2).

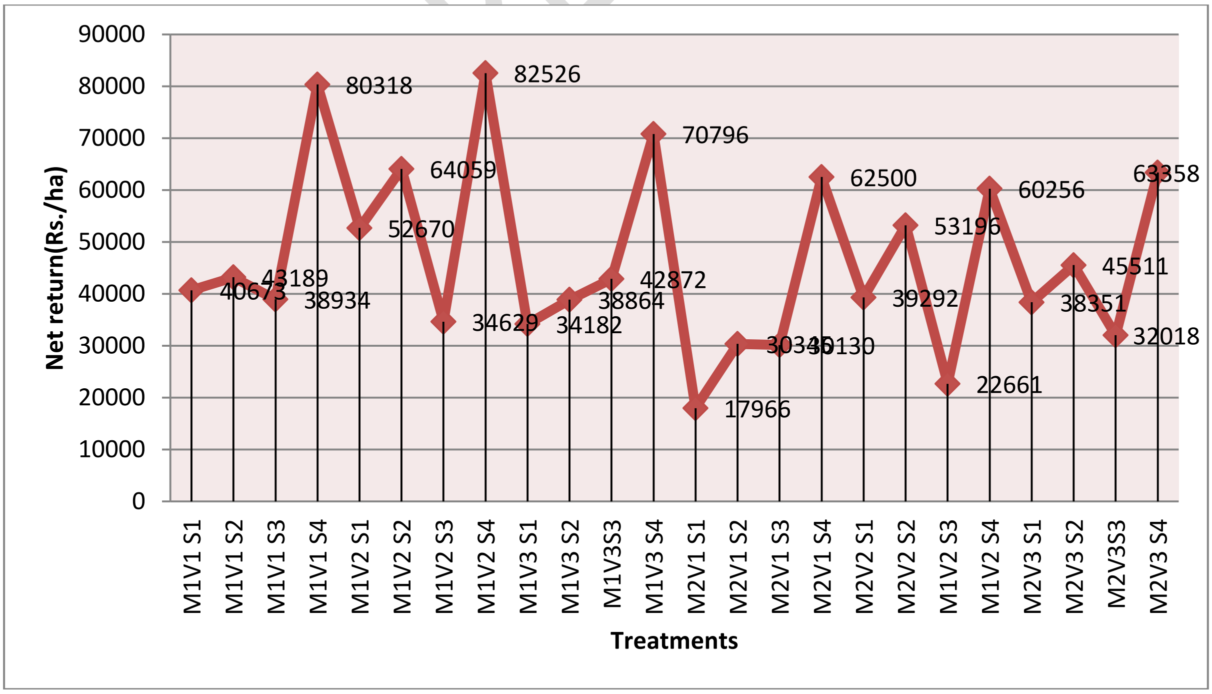

Fig 2: Effect of treatments on net return (Rs./ha)

3.3: Water use efficiency and Water productivity

Higher water use efficiency of 5,77, 5.62 & 6.63 kg/ha.mm-1 was recorded under direct seeded (M_1), 'TKM 13' (V_2) and 20x40x10cm (Paired row)(S_4) compared to other treatments. Similar trend was also observed in water productivity (Rs. 9.23, 8.97 &10.61/m^3). The savings in water in drip irrigated rice fields and increased water productivity and grain yields under aerobic rice systems have also been reported by Soman et al., 2018(4a). Among treatment combinations, direct seeded at raised bed with TKM 13 at the spacing of 20x40x10 cm was recorded the water use efficiency(7.69 kg./ha-mm) and water productivity (Rs.12.30/m^3) compared to other treatment combinations(Fig 3&4). Rakesh Sharda et al.(2014) suggested that the use of micro irrigation in DSR has the potential to increase irrigation WUE by matching the water requirement of the crop, reducing runoff, deep drainage losses and energy saving(5). Technologies like drip and fertigation are going to be answers for the challenges of water and the overall need for high efficiency input management and higher production efficiency also reported by Soman et al., 2018(4b).

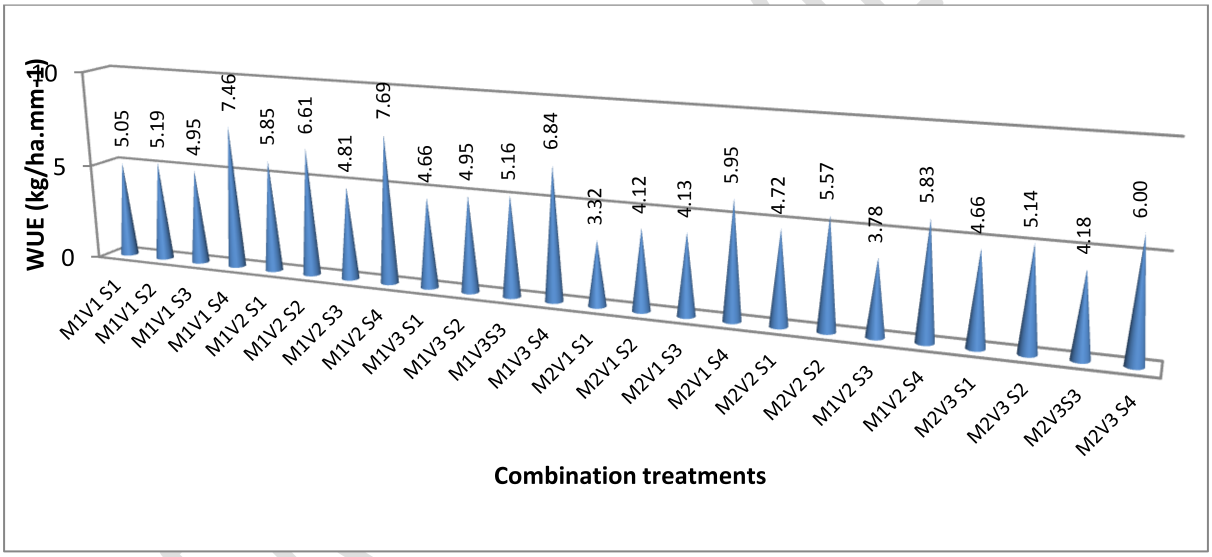

Fig 3: Effect of treatments on Water use Efficiency (kg/ha.mm-1)

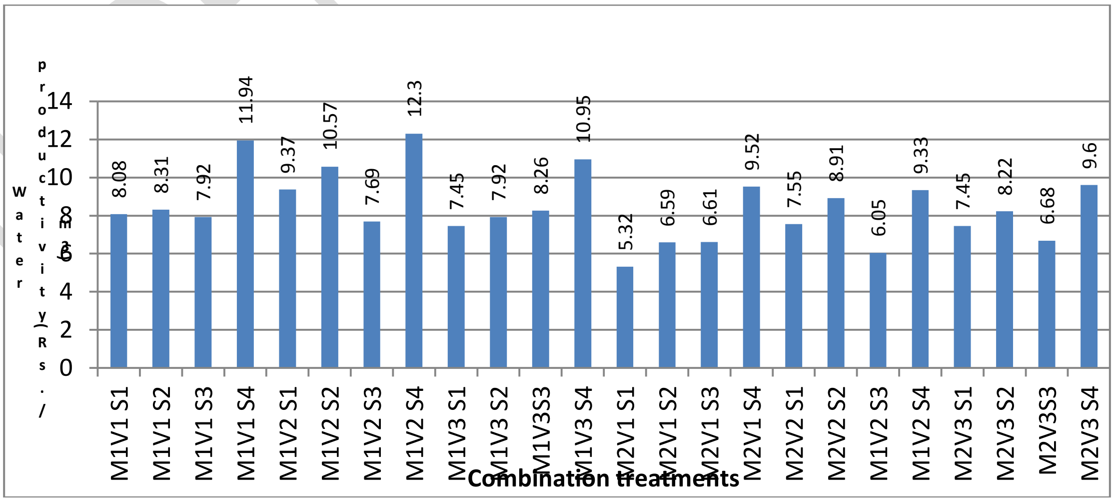

Fig 4: Effect of treatments on Water productivity (Rs./m^3)

4. CONCLUSION

Drip irrigation system with 90 cm lateral spacing, 60 cm dripper spacing with 4lph discharge rate is optimum for rice cultivation under drip irrigation system.

Among the methods of establishment, direct seeding is the best method of establishment for drip irrigated rice cultivation. Among the varieties, 'TKM-13' was performed in all yield parameters. Paired row method of sowing viz., 20 x 40 x 10 cm is the best for drip irrigated system of rice cultivation.

Combination of direct seeded rice with medium duration variety 'TKM 13' at the spacing of 20x40x10 cm is the best for getting higher yield(7075 kg/ha) and net return(Rs. 82526/ha), BCR (2.76),and higher water use efficiency (7.69 kg./ha-mm) in drip irrigated paddy cultivation during *Samba (Rabi)*season.

Direct seedling by using 'TKM 13' with the spacing of 20x40x10 cm(Paired row) in raised bed is the best method of rice cultivation under drip irrigated system during *Samba(Rabi)* season for higher water use efficiency and productivity.

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