CROPPING GEOMETRY AND *IN SITU* SOIL MOISTURE CONSERVATION PRACTICES IN UPLAND RICE (*Oryza sativa* L.)

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by

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2020

DECLARATION

I, hereby declare that this thesis entitled **"CROPPING GEOMETRY AND *IN SITU* SOIL MOISTURE CONSERVATION PRACTICES IN UPLAND RICE (*Oryza sativa* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"CROPPING GEOMETRY AND *IN SITU* SOIL MOISTURE CONSERVATION PRACTICES IN UPLAND RICE (*Oryza sativa* L.)"** is a record of research work done independently by Ms. Gunturi Alekhya (2018-11-055) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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BCR	:	Benefit cost ratio
BD	:	Bulk density
Bt	:	*Bacillus thuringiensis*
CD (0.05)	:	Critical difference at 5 % level
CEC	:	Cation exchange capacity
CGR	:	Crop growth rate
Cm	:	Centimetre
C:N	:	Carbon : Nitrogen ratio
CNRH	:	Chinsurah Rice hybrid
Cob^{-1}	:	Per cob
Cu	:	Copper
DAS	:	Days after sowing
DMP	:	Dry matter production
EC	:	Electrical conductivity
et al.	:	Co-workers/ Co-authors
Fe	:	Iron
Fig.	:	Figure
FW	:	Fresh weight
FYM	:	Farmyard manure
g	:	Gram
g^{-1}	:	Per gram
GKVK	:	Gandhi Krishi Vigyana Kendra
g kg^{-1}	:	Gram per kilogram
Ha	:	Hectare
ha^{-1}	:	Per hectare
HI	:	Harvest index
$hill^{-1}$	:	Per hill
IET	:	Initial Evaluation Testing
INM	:	Integrated Nutrient Management

IW/CPE	:	Irrigation/ Cumulative pan evaporation
K	:	Potassium
KAU	:	Kerala Agricultural University
Kg	:	Kilogram
kg^{-1}	:	Per kilogram
LAI	:	Leaf area index
m^{2}	:	Square metre
m^{-2}	:	Per square metre
m^{-3}	:	Cubic metre
MFC	:	Multi Functional Cross
mg	:	Milligram
Mg	:	Mega gram
ml	:	Milli Litre
mm	:	Millimetre
M ha	:	Million hectare
Mn	:	Manganese
MSL	:	Mean sea level
MT	:	Million tonnes
N	:	Nitrogen
NS	:	Non-significant
P	:	Phosphorus
$Panicle^{-1}$	:	Per panicle
pH	:	Potenz hydrogen
PPFM	:	Pink pigmented facultative methylotrop
PTB	:	Pattambi
RARS	:	Regional Agriculture Research Station
RBD	:	Randomized block design
RCH	:	Rice cotton hybrids
RLWC	:	Relative leaf water content
SPAD	:	Soil plant analysis development
SEm	:	Standard error of mean

SWM	:	South west monsoon
t	:	Tonnes
USDA	:	United states Department of Agriculture
WG	:	Wettable granules
WP	:	Wettable powder
WHC	:	Water holding capacity
WUE	:	Water use efficiency
Zn	:	Zinc
Zn SO_4	:	Zinc sulphate

LIST OF SYMBOLS

%	:	Per cent
@	:	at the rate of
^{o}C	:	Degree Celsius
^{o}E	:	Degree East
^{o}N	:	Degree North
µ	:	Micro
₹	:	Rupee

INTRODUCTION

1. INTRODUCTION

Rice is the most important staple food crop of India, occupying 23.3 per cent of gross cropped area and 43 per cent of the total food grain production, playing an important role in national food supply. India ranks first in area under rice cultivation (431.94 lakh hectares) and second in production after china (110.15 MT) with a productivity of 2550 kg ha^{-1} (DoF, 2018).

The world is experiencing shortage of land and the lowlands are being converted to the uplands. Since the population is growing at a rapid rate, the major agricultural area is now being depleted for several other means, hence the upland areas which are fragile and the forests areas of tropics are used for the sustenance of rural inhabitants. About hundred millions of people are currently depending on the upland rice as their regular basic food. Upland rice producers are one among the deprived farmers of the world (Arraudeau, 1995).

A steady decline in rice cultivation was observed in Kerala since 1980s. The sharp fall in both the area and production of rice in the state had implications for Kerala's social, economic and ecological development. Of the total area under rice cultivation in the country, 6.00 M ha is under rainfed upland rice, which accounts for 13.5 per cent of total area, but the productivity of upland rice is low about 0.9 t ha^{-1} (Thomas, 2011). This low productivity is mainly due to various constraints including both biotic and abiotic stresses. Among abiotic stresses, moisture stress during critical stages lead to severe yield loss owing to its low productivity, and hence proper water management practices has gained paramount importance.

Meeting the irrigation water requirement of the crops is now becoming difficult due to the scarcity of water resources and the world is peeking for water saving agriculture. Diminishing water resources and increasing food demand are the major confronts for the food security in India (Kreye *et al.* 2009). With the declining water availability, paddy production system has to be moved towards water efficient production practices, especially upland rice systems.

With low water availability, suitable modifications in cropping geometry of upland rice is of great importance. In the conventional method of planting rice in 20 cm x 10 cm spacing, the scope for intercropping is meagre. Consequently, widening inter row spacing is one of the pre requisites for growing intercrops. It not only gives paddy yield comparable to the conventional planting system in single rows but also facilitates inter planting and management of intercrops without damaging base crop (Nazir *et al.,* 1988 and Saeed *et al.,* 1999). Many agronomical practices were developed and suggested to increase WUE in crops in which live mulching, use of super absorbent polymers like hydrogels and coir pith compost are important in conserving the moisture. These practices increase the period of moisture availability by increasing the available moisture content in soil.

Live mulch is a cover crop inter planted or sown with a main crop, meant to serve the purpose of a mulch *viz.*, suppression of weeds, regulation of soil temperature and conservation of moisture (Power and Koerner, 1994). It also protects the soil from wind and water erosion and helps to increase the natural enemies of crop pests.

Cowpea is tailored to grow in hot and dry climates (Craufurd *et al.,* 1997) and has traditionally been used for green manure because of its abundant biomass production. In particular, living mulch with cowpea (legumes) will increase the nitrogen content of soil by biological nitrogen fixation and thereby reduces the need for chemical fertilizer application. Mulching is a potential method for efficient water use in upland rice cultivation. Live mulching with legumes is a beneficial practice for enhanced moisture conservation and is found to benefit both short and long term productivity of crops by improving soil physical properties, reducing runoff and erosion and suppressing weeds (Aparna, 2018).

Hydrogel is a super absorbent polymer, cross linked poly acrylamide, hydrophilic and decomposable amorphous polymer which can absorb and retain water about 400 times of its actual mass and 95 % of absorbed water was made available for crop (Johnson and Veltkamp, 1985). Hydrogels not only increase moisture availability in root zone of crop, but also improves the fertilizer use efficiency and also physical properties of soil. Hydrogels are registered to be a new technology to improve the WUE and thereby reduce the irrigation frequency. Hydrogels are ecofriendly and can be degraded by both living and non-living factors of environment to moderate extent after certain period of time (Narjary *et al.,* 2015). Moisture availability is an important factor limiting the growth of plants, employment of agricultural hydrogels has immense potential to improve all the properties of soil apart from water storage which leads to better growth and yield of plants.

Coir pith is a waste from coir industry, utilization of coir pith forms a kind of recycling to achieve better resource use and environment protection. The composted coir pith is effective and it improves the yield and also maintains the soil fertility (Solaimalai *et al.*, 2001). The specific structure of the coir pith compost helps to retain water and oxygen and prevents loss of vital nutrients from the farm. Coir pith compost improves the soil texture, structure, soil aggregation, water holding capacity (higher than 5 times of original weight) contributing towards increased soil moisture. The bulk density is reduced to considerable extent, increases soil native micro flora (Joshua *et al.*, 2012).

The studies on integration of cropping geometry, *in situ* soil moisture conservation practices for optimization of productivity of rice under upland conditions are lacking. There is a prospect for increasing productivity of upland rice by adopting proper geometry along with moisture conservation practices. Therefore, the present study entitled “Cropping geometry and *in situ* soil moisture conservation practices in upland rice (*Oryza sativa* L.) was carried out with the following objectives

- To study the influence of cropping geometry and *in situ* soil moisture conservation practices on growth and yield of upland rice.
- To workout the economics of cultivation.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

About 40 percent of rice area in India is grown under rainfed conditions. Of these total rainfed area, 23 percent are rainfed uplands, which are drought prone. The upland ecosystem occupies an area of 8 m ha, of which 6.2 m ha are in eastern region of the country. Although the potential yield of upland rice varieties can be up to 4.5 to 6.0 t ha^{-1}, the average yield of upland rice is usually less than 2.0 t ha^{-1} in farmers field and this is due to several environmental and socio economic constraints in which moisture stress at the time of anthesis and grain filling reduces head rice recovery and increases grain chalkiness, which is an important limitation for achieving higher yield from this ecology.

In this chapter, efforts have been made to briefly review the outline of important research works carried out by earlier workers on the cropping geometry and *in situ* soil moisture conservation practices like use of super absorbent polymer hydrogel, live mulching with cowpea, coir pith compost on growth and yield of upland rice are presented.

2.1 INFLUENCE OF CROPPING GEOMETRY AND *IN SITU* MOISTURE CONSERVATION PRACTICES ON GROWTH CHARACTERS

2. 1. 1 Effect of cropping geometry

Narrow spacing of 10 cmx 10 cm resulted in significantly higher values of both Leaf Area Index and dry matter production and gradually decreased with enlarged spacing (Murty and Murty, 1980). Wider spacing ensured in maximum number of functional leaves, leaf area and the number of tillers (Shrirame *et al.* 2000). Dry matter production plant $^{-1}$ was improved under paired row bed furrow method (15.05 g $plant^{-1}$) compared to normal flat bed method of planting (12.97 g $plant^{-1}$) as reported by Dutta (2006) in groundnut.

A study conducted by Sivagamy and Rammohan (2013) on the effect of different cropping geometries on yield and quality of sesame reported that sesame sown at wider spacing of 45 cm x 15 cm showed significantly taller plants during all the stages of observation and the shortest height plants were observed under closer spacing of 15 cm x 10 cm. The reason behind this might be the wider geometry provided sufficient space for rooting and extraction of moisture to the plants which consecutively helped in better water and nutrient absorption resulting in the production of taller plants.

High LAI (leaf area index) of 2.21 at 60 DAS was noticed under closer planting geometry at a spacing of 15 cm x 10 cm compared to wider spacing, which is due to added number of plants per unit area, which indicates increased number of leaves throughout the plant growth period. Significant increment in plant height, number of branches plant^{-1} and dry matter plant^{-1} was observed at all growth stages under cropping geometry with spacing of 50 cm × 25 cm over 60 cm x 25 cm in dill (Mehta *et al.,* 2012).

Under wider row crop geometry of 60 cm x 19 cm, growth attributes viz., plant height (182.9 cm), leaf area index (3.41) and dry matter production (7435 kg ha^{-1}) were higher compared to narrow row cropping geometry of 45 cm x 25 cm. Taller plants produced under 60 cm x19 cm might be due to competition of plants for light under narrow plant to plant space and better availability of resources between wider row spacing (Thavaprakash *et al.,* 2005). Crop geometry and nutrient management practices considerably affected the plant height of rice cultivars. Plant height of CNRH-3 rice cultivar showed greater plant height (88.66 cm) over Pro Agro 6201 variety (88.42 cm), crop geometry of 15cm x 15cm showed greater plant height (88.42 cm) than 25 cm x 25cm (86.16 cm) (Bezbaruha *et al.,* 2011).

2. 1. 2 Effect of live mulching of cowpea

Live mulching is identified as a potential method for conserving the soil moisture in parts of upland rice (Totin *et al.,* 2013).

Taller plants with high LAI, increased number of tillers hill^{-1} and DMP in rice was observed in plots with green manuring over control (Hemalatha *et al*., 2000). Cowpea intercropped with upland rice in the ratio of 3:1 was found to produce taller plants compared to mono cropping and LAI was higher in rice crop intercropped with cowpea, along with N and P fertilizer application (Srinivasan, 2002).

Singh (2005) reported significantly taller plants in upland rice intercropped with cowpea + 50% N, P. Cowpea was the best suitable crop for the purpose of green manure under upland rice conditions (Ratilla and Escalada, 2006). Kayeke *et al*. (2007) reported significant increase in plant height and number of tillers by green manuring in upland rice. Significant difference in plant height was observed both at vegetative stage and maturity stage by incorporation of green manure cowpea in comparision to the plots without cowpea (Okonji *et al.,* 2011).

Incorporation of cowpea residue was found to increase the height of plant, tiller number m^{-2} and dry matter accumulation in aromatic variety of rice (Jat *et al.,* 2011). Cowpea is used as green manure crop even in maize, Fabunmi and Balogun (2015) reported significantly taller plants of maize with cowpea as a green manure over control plots. Live mulching of upland rice with cowpea and its subsequent incorporation before flowering stage improved the height of plant and total dry matter production (Aparna, 2018). Langangmeilu (2019) reported that *in situ* green manuring of cowpea and subsequent incorporation in upland rice along with application of 45 kg P_2O_5 ha^{-1}, 120 kg N ha^{-1} with 50% N as chemical fertiliser and 25% N as FYM and *in situ* green manure cowpea produced taller plants and increased dry matter accumulation.

2. 1. 3 Effect of hydrogel

The artificially prepared / designed polymers are generally present in crystal, granule or in powder form which are obtainable in many trade names like super absorbent polymers, jalasakthi granules, root watering, drought crystals, which are collectively termed as hydrogels. Hydrogels aid in supplying the moisture according to the crop needs in order to protect them from moisture stress conditions over period of time (Akhter *et al.,* 2004).

The ability of hydrogel in water absorption increased the dry matter production (DMP), which resulted in improved plant growth (Johnson and Veltkamp, 1985). Under water limited conditions, the existence rate of plant was increased about 1.5 to 1.6 times with the addition of hydrogel (Callaghan *et al.,* 1988).

The plant height (79 cm), number of effective tillers (264 m^{-2}) were improved profoundly by addition of hydrogel in aerobic rice compared to that of control plots (Rehman *et al.,* 2011).

Photosynthetic ability of a plant is decided by its leaf area. Addition of hydrogel not only increased the leaf area but also improved growth parameters like CGR (crop growth rate), total dry matter production and yield of soyabean (Yazdani *et al.,* 2007).

2. 1. 4 Effect of coir pith

Application of composted coir pith along with $ZnSO_4$ and inorganic nitrogen improved the number of tillers and dry matter accumulation by increased availability of N and P, which induced better plant growth and improved physiological conditions as reported by Ramesh *et al.* (2006) in pearl millet. Munda *et al.* (1983) reported, application of coir pith compost along with the inorganic N and zinc sulphate enhanced the number of tillers. Growth of plant and the physiological activities were improved by the better N availability. Increased P availability induced positive effect on cell division, formation of albumin and root development, which collectively contributed to the enhanced production of tillers. Influence of coir pith compost on the growth attributes like leaf area index (LAI) and dry matter production (DMP) was observed during the booting stage of the crop. This is because of high C:N ratio which leads to temporary immobilization of N in the early stages of the crop as reported by Krishnan (1986). Dry matter production (DMP) of sorghum under rainfed conditions was significantly increased by the addition of coir pith to the soil (Kandiannan, 1988). In reference to the combined effects of organic ammendments and inorganic fertilizers, it is found that organic ammendments addition resulted in more dry matter production at different levels of IW/CPE ratio as reported by Lourduraj (2000) in groundnut.

2. 1. 5 Combination effects

Combined effects of hydrogel with mulch showed significant difference in plant height only at 30 DAS. During 60 and 90 DAS, the plant height was not influenced among different levels of hydrogel and mulch, but in comparison with the control, there was a significant difference in plant height at 30 and 60 DAS. Effect of hydrogel at different levels in combination with different types of mulch showed no positive relation with the number of leaves plant^{-1} but showed major difference with absolute control at 30 and 90 DAS (Kumar *et al.,* 2018). A considerable difference was observed in leaf area plant^{-1}, LAI and dry matter production in hydrogel and mulch interactions in addition to control.

2.2 INFLUENCE OF CROPPING GEOMETRY AND *IN SITU* SOIL MOISTURE CONSERVATION PRACTICES ON YIELD ATTRIBUTES

2. 2. 1 Effect of cropping geometry

Cropping geometry is an important factor that limits the yield of upland rice (Sakariyawo *et al.,* 2014).

Narrow spacing showed a positive effect on productive tillers m^{-2} and the remaining yield characters were enhanced with the wider spacing (Venkateswarlu and Mahatim, 1980). Significant increase in number of filled grains $panicle^{-1}$ was recorded under spacing of 20 cm x 20 cm and prominent decrease in filled grains was noticed with every consecutive reduction of 5 cm space within a row (Varma *et al.,* 1991).

According to Kewat *et al.* (2002), 20 cm x 10 cm spacing resulted in higher grain and straw yield (6.3 t ha^{-1} and 16.2 t ha^{-1}) respectively, with a B:C ratio of 2.8 and was significantly superior to wider spacing of 20 cm x 15 cm and 20 cm x 20 cm. Rajesh and Thanunathan (2003) reported that significantly higher yield was obtained under wider spacing of 20 cm x 15 cm compared to 20 cm x 10 cm.

According to Thavaprakash *et al.* (2005), the yield characters like the length, diameter and weight of the cob, green yield of cob and fodder yield were highest under wider cropping geometry (60 cm) compared to cropping geometry with row spacing of 45 cm, however the intercrop yield was higher under closer row geometry of 45cm compared to 60 cm. Highest seed cotton yield (3230 kg ha^{-1}) was obtained for *Bt* cotton RCH134 variety under crop geometry of 67.5 cm x 60 cm with fertilizer dose of 187.5 kg ha^{-1}N, 75 kg ha^{-1} P_2O_5 and 75 kg ha^{-1} K_2O compared to the other two spacing of 100 cm x 45 cm and 100 cm x 60 cm (Bhattoo *et al.,* 2011). The yield of rice was found to be increased by adopting narrow row spacing compared to normal spacing (Dass *et al.,* 2017).

A study conducted by Mehta *et al.* (2012) on effect of irrigation, nutrient levels and cropping geometry on growth and yield of dill showed higher biological yield (3.3 t ha^{-1}) with seed yield of 1.2 t ha^{-1} and straw yield of 2.1 t ha^{-1} at crop geometry of 50 cm × 25cm over 60 × 25 cm. An experiment including combinations of cropping geometry in main plots and nutrient management practices in sub plots of CNRH -3 rice variety showed the highest grain yield in the cultivars grown at 20 cm x 20 cm spacing compared to 15 cm x 15 cm. It is also reported that the yield attributing characters like number of productive tillers, panicle length and weight, number of grains panicle^{-1}, test weight and harvest index were also improved (Bezbaruha *et al.,* 2011). Transplanted pigeonpea as a sole crop under cropping geometry of 120 cm x 60 cm produced higher yield than intercropped transplanted pigeonpea (120 cm x 60cm), direct sown sole pigeonpea (90 cm x 30 cm) and direct sown intercropped pigeonpea (90 cm x 30 cm) (Sujatha and Babalad, 2019).

2. 2. 2 Effect of live mulching of cowpea

The grain yield and other yield attributes like total number of grains, number of filled grains and its test weight were improved significantly for rice crop, which is intercropped with cowpea, in 2:1 ratio (Singh, 2005). High yield was reported by Oroka and Omoregie (2007) in the rice crop intercropped with cowpea. Raising cowpea as an intercrop with rice under semi dry conditions and its incorporation enhanced the overall productivity of rice crop (KAU, 2016).

The length of panicle (26.4 cm), number of grains panicle^{-1}(126), thousand grain weight (42.9 g) and yield (2.6 t ha^{-1}) were significantly enhanced by application of cowpea residue in rice (Okonji *et al.,* 2011). The highest grain yield, 1000 grain weight, number of grains row^{-1}, and number of rows cob^{-1} was observed in maize by the application of cowpea live mulch @ 22 plants m^{-2} compared to 7 plants m^{-2}. Weeds are not completely controlled by cowpea live mulch applied @ 7 plants m^{-2} which lead to decreased yield components particularly the number of grains cob^{-1} (Talebbeigi and Ghadiri, 2012).

2. 2. 3 Effect of hydrogel

The number of grains panicle^{-1} and grain yield was significantly improved by the application of hydrogel in aerobic rice (Rehman *et al.,* 2011). Seed treatment of bajra with hydrogel @ 10-20 g kg^{-1} improved the number of effective tillers m^{-2}, length of ear, grain and stover yield (Singh, 2012).

Increase in grain yield and total biomass by 15% and 23% respectively was obtained as a result of addition of hydrogel @ 1.87 g kg^{-1} of soil as reported by Volkamar and Chang (1995) in barley crop. In groundnut, significant increase in growth, number of branches, total biomass, pod yield, seed yield and 100 seed weight was observed by the application of hydrogel @ 200 kg ha^{-1} (Langaroodi *et al.,* 2013).

Hydrogel application @ 20 kg ha^{-1}significantly improved the number of cobs plant^{-1}, shelling percentage and test weight in maize compared to hydrogel application @ 15 kg ha^{-1} and control (Kumari *et al.,* 2017).

2. 2. 4 Effect of coir pith

Higher yield of groundnut was recorded by the application of coir waste compared to pressmud, FYM (Mayalagu *et al.*, 1983) and significantly higher growth, yield attributes and pod yield of ground nut was also observed by the addition of coir waste along with recommended N, P, K fertilizer dose (Nagarajan *et al.*, 1985). By the addition of coir waste @ 20 t ha^{-1} enhanced the groundnut pod yield (Durai and Rajagopal, 1983) and application @ 10 t ha^{-1} improved the grain yield of maize significantly over the control (Krishnan, 1986) and also reported in finger millet (Lavanya, 1994).

The yield of crops such as sorghum, pearl millet, finger millet, maize and cotton under rainfed condition was increased to the tune of 10-30% compared over control by the application of coir pith as reported by many workers (Anabayan, 1988; Athamanathan, 1996; Veerabadran, 1991). In sugarcane crop, application of coir pith@ 30 t ha^{-1} along with nitrogen fertilizer increased the growth and yield (Singh *et al.,* 1989) and addition of coir pith as a mulch @ 25 t ha^{-1} at 2 DAP along the ridges and furrows improved the sugar and cane yields (Saminathan, 1990).

Application of coir pith compost @ 12.5 t ha^{-1} along with the chemical fertilizers was found to enhance the number of productive tillers, grains panicle^{-1} and test weight in rice (Parasuraman *et al.,* 2003). In a study conducted by Sushma *et al.* (2007), application of coir pith based compost with press mud and 100% fertilizer recommended dose resulted in higher grain and straw yield of 3.75 t ha^{-1} and 7.60 t ha^{-1} respectively in ragi.

2. 2. 5 Combination effects

Kumar (2018) reported that mulch and hydrogel applied treatments resulted in improved yield attributes and yield in maize.

2.3 INFLUENCE OF CROPPING GEOMETRY AND *IN SITU* SOIL MOISTURE CONSERVATION PRACTICES ON PHYSIOLOGICAL AND CHEMICAL ESTIMATIONS

2. 3. 1 Effect of cropping geometry

Thavaprakash and Velayudhan (2007) conducted a study on the effect of crop geometry, intercropping systems and INM practices on cob yield and nutrient uptake. They reported that higher uptake of N, P, K was observed in baby corn spaced at 60 cm x 19 cm compared to the one spaced at 45 cm x 25 cm. Maximum uptake of N, P, K and was observed in cropping geometry of 20 cm x 20 cm along with inorganic fertilizers compared to 25 cm x 25 cm, whereas soil residual fertility was highest at spacing of 15 cm x 15 cm over other spacing (Bezbaruha *et al.,* 2011).

Cropping geometry did not have influence on the available P and K status. A rising trend in uptake of nutrients was recorded under paired row method of planting than flatbed method in groundnut (Dutta, 2006). Under wider row spacing (75 cm) the nutrient uptake was significantly improved compared to narrow row spacing (60 cm) and this might be due to improved dry matter accumulation that in turn improved the nutrient uptake. Soil sample analysis after harvest showed that available N was more under wider spacing (75 cm x 16 cm) than narrow spacing (60 cm x 20 cm). This was due to dynamic growth of plant under wide row spacing, which used large amounts of N and hence left lesser in soil (Rathika, 2013).

2. 3. 2 Effect of live mulching of cowpea

Sharma *et al*. (2010) quantified the organic carbon and total nitrogen in live mulching with legumes and weeds in maize. Results indicated that contents of organic carbon and total nitrogen in soil were more in live mulching with legumes than weeds and also improved the soil health in rainfed cropping system of maize-wheat under Doon valley conditions.

Crop live mulch self-possessed of crop residues significantly upgraded the soil fertility when using *Viciada sycarpa* (grazing vetch) and *Pisum sativum* (forage pea) for mulch by improving soil N up to 5 cm soil depth, with values of 84 mg N kg $^{-1}$ and 64 mg N kg $^{-1}$ than other treatments (Murungu *et al.,* 2011). Warren *et al.* (2015) observed that live mulch in broccoli with mixture of Italian ryegrass and white clover in 1:1 ratio (by seed weight) resulted in the low nitrogen uptake by the crop as compared to crop without live mulch and concluded that it was due to competition for nitrogen between crop and crops used for live mulch.

Ram *et al*. (2017) reported that highest nutrient removal of N, P and K by grains and stover in *rabi* maize was found higher in live mulch with vegetable cowpea than that of control. Green manuring with cowpea along with the application of N and P improved RLWC of upland rice (Aparna, 2018 and Langangmeilu, 2019).

2. 3. 3 Effect of hydrogel

A study conducted by Orzolek (1993), indicated that application of hydrogel to the soil showed an increase in the water holding capacity and nutrient reserves of soil. Bredenkamp (2000) reported that hydrogel application improved uptake of nutrients especially N, P and K. Aqua-Soil TM (hydrogel) along with the slow release and standard fertilizers retained up to 400% N and 300% K more than control.

Borivoj *et al.* (2006) reported that addition of hydrogel to the sandy soils enhanced enzymatic activities like dehydrogenase, protease, urease, acid phosphatase and alkaline phosphatase, which indicates microbial population of soil. Wu *et al.* (2008) observed that application of 28 kg ha^{-1} of hydrogel (Bhagiratha) with fertilizers at recommended rates in pigeon pea resulted in the high soil moisture content level in sandy and also improved uptake of nutrients by the effective utilization of applied fertilizers and water resources.

Application of medium, high and very high doses of hydrogel remarkably increased the total N content in the surface soil (0-15 cm) by 19.3%, 36.6 % and 35.8% respectively, enhanced the available P content by 20.5%, 44.3% and 55.6% correspondingly and exchangeable K content also increased incredibly (Islam *et al.*, 2011). Mondal (2011) reported that use of hydrogel in loam soil at different growth stages of crop and produced higher seed yield and nitrogen uptake by 12 and 10%, respectively as compared to control (only fertilizers).

Barihi *et al.* (2013) stated that the use of super absorbent polymer of ABA 200 resulted in increased storage of nitrogen in cucumber. It influences the optimal use of fertilizers in crops in regions of arid and semi-arid areas (Dabhi *et al*., 2013) and thereby increased the values of crude protein percentage in wheat crop (Ashkiani *et al*., 2013).

De Mamann *et al.* (2017), reported that there was increase in fertilizer use efficiency, in particular N use efficiency by the application of hydrogel at the rate of 30 and 60 kg ha^{-1} in wheat crop under sequential cropping system.

Ashraf *et al.* (2018) reported an increase in the RLWC by the application of hydrogel @ 5 kg ha^{-1} along with the foliar spray of PPFM @ 500 ml ha^{-1} under broad bed and furrow system in cotton.

2. 3. 4 Effect of coir pith

An increase in the P_2O_5 content in significant amount by the addition of coir waste @ 5 t ha^{-1} to the soil has been reported (Loganathan and Lakshminarasimhan, 1999). Increased availability of N, P, K to the crop was observed by the application of coir pith waste to the saline soils (Clarson *et al.* 1983). The nutrient status of soil was enhanced as a result of application of coir waste (Lavanya, 1994). Appreciable increase in the organic carbon content of the soil cropped with rainfed sorghum was observed by Pushpanathan (1987) with the single application of raw coir pith.

Combined application of coir pith compost and gypsum significantly enhanced the available N, P, K content of soil at different crop growth stages of groundnut (Muthulakshmi, 1988). Ammal and Muthaiah (1995) reported that addition of coir pith compost @ 12.5 tha^{-1} significantly increased the nutrient uptake (N, P, K) by the rice crop.

Solaimalai *et al.* (2001) stated that raw coir pith compost application and recommended dose of inorganic fertilizers resulted in higher values of soil available nutrient status and their uptake by the crop. Higher amounts of potassium availability in the soil was observed under coir waste treated plots compared to FYM applied plots

Application of composted coir pith @ 12.5 t ha^{-1} resulted in reduction of pH, EC and increased the availability of macro and micro nutrients (Rangaraj *et al.*, 2007)

Addition of coirpith based compost in the soil resulted in the increased availability of N, P and S as compared to that of control in ragi (Sushma *et al.*, 2007).

2. 3. 5 Combination effects

Kumar *et al.* (2018) concluded that the interaction of hydrogel and rice husk mulch application @ 1.25 kg ha^{-1} and 5 t ha^{-1} respectively resulted in the highest availability of soil phosphorous, whereas other nutrients like nitrogen and potassium were recorded high with the control.

2.4 INFLUENCE OF CROPPING GEOMETRY AND *IN SITU* SOIL MOISTURE CONSERVATION PRACTICES ON ROOT PARAMETERS

2. 4. 1 Effect of cropping geometry

Crop geometry showed considerable difference in biomass partitioning of root, leaf and stem in baby corn. Baby corn grown at spacing of 75 cm x 16 cm produced more root biomass of 125 kg ha^{-1}than at 60 cm x 20 cm (Rathika, 2008).

The root length, number of root branches and nodules $plant^{-1}$ were increased under 45 cm x 15 cm spacing with 60 kg of phosphorous ha^{-1} subsequently under 45 cm x 15 cm with 50 kg phosphorous $ha^{-1}$and 30 cm x 15 cm with 60 kg ha^{-1} of P_2O_5 (Shukla *et al.,* 2017).

2. 4. 2 Effect of live mulching of cowpea

Ghosh *et al.* (2006) reported that the crop root growth was improved in groundnut by mulching which was found to act as a buffer against temperature fluctuations and moisture.

2. 4. 3 Effect of hydrogel

Meena *et al.* (2011) reported that increased concentration of hydrogel resulted in improvement of root parameters like increased root length, root volume, root fresh weight, dry weight and root shoot ratio in tomato crop. Application of hydrogel @ 1.4 g pot^{-1} in root zone of pearl millet improved the dry weight of roots in loamy sand soil in comparision to loamy soil (Keshavars *et al.*,2012). In the sequential cropping system (soyabean and wheat), the root growth and water use efficiency of both the crops were improved (Narjary and Aggarwal, 2014).

2. 4. 4 Effect of coir pith

A study conducted by Dharani and Sarojini (2014) revealed that coir pith compost application at different concentrations in sugarcane crop resulted in the increased growth of shoot and root length than the sugar cane plant growth without the application of coir pith compost.

2. 4. 5 Combination effects

Application of hydrogel along with mulch improved the root growth by increasing the availability of nutrients and moisture in maize (Kumar, 2018).

2.5 INFLUENCE OF CROPPING GEOMETRY AND *IN SITU* SOIL MOISTURE CONSERVATION PRACTICES ON SOIL PROPERTIES

2. 5. 1 Effect of cropping geometry

The treatment combinations involving cropping geometry and phosphorus levels showed considerable improvement in soil health by enhancing the soil microbial activity. It also improved soil physical properties viz., soil structure, texture, porosity, aeration and water holding capacity (Shukla *et al.*, 2017).

2. 5. 2 Effect of live mulching of cowpea

Soil physical and chemical properties were improved by growing of green manure crops or cover crops (Lal *et al.*, 1978; Buresh and De Datta, 1991).

The inherent fertility of soil was maintained and the organic matter content was enhanced by green manuring (Gauther and Guilbeau, 1979). High soil organic carbon content was observed by Prasad and Misra (2001) with incorporation of green manure cowpea or Sesbania after the harvest of rice.

Addition of 50% of N through NPK fertilizers and 50% of N through green manure reduced the bulk density of soil (Bajpai *et al.*, 2006). Lower bulk density was observed in plots treated with green manures in comparision to plots without green manure (Narayan and Lai, 2006). Ratilla and Escalada (2006) reported that upland rice intercropped with cowpea reduced bulk density of soil. Organic matter content and the physical properties of soil were improved by intercropping cereals with legumes (Alom *et al.*, 2010).

2. 5. 3 Effect of hydrogel

The water holding capacity (WHC) of sand increased from 171 percent to 402 percent by the application of hydrogel @ 2g kg^{-1} and thereby the irrigation requirement also significantly reduced (Johnson, 1984). Taylor and Halfacre (1986) investigated and reported that addition of hydrogel decreased the irrigation requirement of several crops by delaying the onset of permanent wilting point percentages even under high evaporation rates. Kaith *et al.* (2013) conducted a study and reported an increase in soil water retention capacity by 52 percent and 72 percent in sandy loam soil and clay soil respectively by the application of hydrogel.

2. 5. 4 Effect of coir pith

Throughout the crop growth period, high soil moisture content was maintained in plots treated with coir pith compost and its incorporation in larger quantities reduced the bulk density, increased the infiltration rate, hydraulic conductivity of soil, thus improving the water holding capacity of the soil (Mayalagu *et al.* 1983, Ramaswamy and Sreeramulu, 1983). Increased soil moisture content was observed by application of coir pith compost as reported by (Anabayan and Palaniappan, 1991).

Rangaraj *et al.* (2007) reported that pH, EC, soil organic matter content, macro nutrients (N, P, K), micro nutrients (Zn, Cu, Mn, Fe) and microbial population were significantly improved by the addition of coir pith compost. Bedi *et al.* (2009) conducted a study on the long term effects of organic and inorganic fertilizers on nutrient build up in soil and their relationship with microbial properties in rice-wheat cropping sequence and reported that with the application of organic sources of nutrients all the physical (permanent wilting point, water holding capacity, bulk density), chemical (organic C, pH, cation exchange capacity) and biological properties (microbial biomass carbon, total microbial count and soil respiration) were improved as compared to inorganic sources of nutrients.

Coirpith compost as a mulch, applied @ 2.5 t ha^{-1}showed maximum porosity (43.56%) and was significantly superior to rice husk and straw mulch. This maximum porosity of coir pith mulch may be due to its fine texture. The gums released by the microbes, which are present in the compost material acted as a binding agent and improved the soil physical properties (Bhatia and Shukla, 1982). Application of coir pith waste @ 10 t ha^{-1} in sandy loam and sandy clay loam soils as reported by Durai and Rajagopal (1983) improved physical properties viz., hydraulic conductivity and infiltration rate. Uguru *et al.* (2015) witnessed increased porosity as a result of mulching.

2. 5. 5 Combination effects

A study conducted by Kumar *et al.* (2018) on combination of different types of mulches with various levels of hydrogel, their interactions along with control were statistically evaluated on physical (porosity and bulk density) and chemical properties (N, P_2O_5, K_2O) of soil. Results indicated that hydrogel added @ 3.75 kg $ha^{-1}$and coir pith compost @ 2.5 t ha^{-1} resulted in maximum porosity of soil.

2.6 INFLUENCE OF CROPPING GEOMETRY AND *IN SITU* SOIL MOISTURE CONSERVATION PRACTICES ON WEEDS

The yield losses due to weeds is about 70-80% in DSR (direct seeded rice) and weed management by herbicide is the most widely and commonly adapted strategy, but continuous use of herbicides having similar mode of action will result in herbicide resistance in different biotypes of weeds. Hence, ecological approaches like alterations in seed rates, planting patterns, weed-competitive cultivars and live mulching with cowpea could be used to reduce the weed problem (Dass *et al.*, 2017).

In comparision to wider spacing, crops which are planted at condensed row spacing with high crop density exploit the resources rapidly and its vulnerability to weed competition also gets reduced (Medd *et al.*, 1985).

Reduced spacing of rows under paired row planting was found to improve weed control by enhancing the competitive nature of crop over weeds by decreasing the transmittance of light to the surface soil (Tharp and Kells, 2001) and also by increasing its canopy growth at a faster rate (Chauhan and Johnson, 2010; Chauhan and Johnson 2011). In aromatic rice, P.Mehak 1, no effect on weed dry matter was observed by changing planting pattern, whereas in PR 115, weed dry matter production (244 g m^{-2}) was greater in case of uniform planting, compared to paired row planting (183 g m^{-2}) (Mahajan and Chauhan, 2011).

Weed dry matter of aerobic rice variety, IET-21214 indicated lowest values under paired rows pattern combined with consequent application of pendimethalin followed by bispyribac-sodium compared to nontreated plots under uniform row pattern (Mahajan *et al.*, 2014).

Cowpea is the most commonly used crop as live mulch and it has an effect on weed growth suppression through different mechanisms. Usually the seed germination gets inhibited due to the absence of red light. The leaf canopy of cowpea filters the red light which lowers the transmission of red to far-red light ratio and thus inhibits seed germination (Taylorson and Borthwick, 1969).

The decreased weed growth by cowpea live mulch might be due to the changes observed in soil temperature, physical hindrances to weed seedlings or due to the release of allelopathic chemicals (Facelli and Pickett, 1991; Teasdale and Mohler, 1993; Teasdale, 1996).

The red light and the moisture, which are essential for germination of the seeds are reduced by cowpea live mulch (Teasdale and Mohler,1993). Zimdahl (1999) reported that intercropping suppresses weeds especially when, bushy and short statured cowpea varieties are grown. Growing cowpea as a living mulch and retaining it to a period even after 60 days after planting in bell pepper (*Capsicum annum* L.) reduced weed populations to a greater extent (Hutchinson and Giffen, 2000).

Living mulch performs as one of the tool of weed management through the competition for light and other resources with weeds (Brady and Weil, 2002). Mashingaidze (2004) reported that the germination and growth of weeds were suppressed by growing Cowpea cultivars with a prostrate, vining and dense crop canopy apart from acting as live mulch.

2.7 INFLUENCE OF CROPPING GEOMETRY AND *IN SITU* SOIL MOISTURE CONSERVATION PRACTICES ON ECONOMICS OF CULTIVATION

Intercropping is an important agricultural technique that improves diversification of food supply (Francis, 1985) and ensures higher economic returns (Norman *et al.*, 1982). Saeed *et al* (1999) reported, rice intercropped with forage legumes resulted in considerable reduction in the plant biomass and yield ha^{-1}, but the additional fodder yield obtained from the intercrop not only compensated the reduction in biomass and yield but also improved the farm net income by 19.69 percent.

Mehta *et al.* (2012) reported that application of irrigation at interval of 15 days with addition of 90 kg N and 40 kg P_2O_5 ha^{-1}under crop geometry of 50 cm × 25 cm was found to be optimum for getting higher biological (seed and straw) yield, productivity and profitability as well as net return of Rs. 15,428 ha^{-1} with benefit cost ratio of 0.74 in comparision with the normal cropping geometry of dill. The economics of sugarcane cultivation was improved by increasing gross return, net return (Rs. 1,10,951.00) and benefit cost ratio (1.95) by the addition of pusa hydrogel @ 2.5 kg ha^{-1} and irrigation scheduled at IW/CPE ratio (0.75) with additional income of ₹ 5,3339.00 ha^{-1} over control (Singh *et al.*, 2018).

2.8 Status of present research and research gaps

Upland rice is mainly grown as a rainfed crop in Kerala with the onset of SWM. As per the POP recommendations of KAU (2016), upland rice is grown at a spacing of 20 cm between rows and 10 cm between plants in a row (normal planting) and the rows of 20 cm can be used for growing intercrop like cowpea. In paired row planting as per the present study, spacing between two rows is reduced to 10 cm and two such paired rows are spaced at 40 cm and this 40 cm gap can be used for growing crop like cowpea. Comparision of paired row planting with normal planting has to be undertaken for studying the influence of cropping geometry on growth and yield of upland rice.

As upland rice is grown as a rainfed crop, soil moisture content is an important limiting factor for growth and productivity. The moisture obtained through rainfall has to be properly conserved in soil through *in situ* soil moisture conservation practices like live mulching of cowpea, application of hydrogel and coir pith compost. Study conducted by Aparna (2018) and Langangmeilu (2019) showed that, *in situ* growing of cowpea as a live mulch and its subsequent incorporation at 45 DAS is found to conserve soil moisture and showed favourable influence on growth and yield of upland rice. Comparative advantage of other soil moisture conservation practices like hydrogel and coir pith compost in relation to live mulching of cowpea has to be studied. Studies on the combined effect of cropping geometry and *in situ* soil moisture conservation practices like live mulching of cowpea, application of hydrogel and coir pith compost on growth and yield of upland rice are limited in Kerala. The present experiment is envisaged to study the combined effect of cropping geometry and *in situ* soil moisture conservation practices like live mulching of cowpea, application of hydrogel and coir pith compost on growth, yield and economics of cultivation of upland rice.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

An experiment entitled "Cropping geometry and *in situ* soil moisture conservation practices in upland rice (*Oryza sativa* L.)" was carried out at the Instructional farm, College of Agriculture, Vellayani, Thiruvananthapuram during *kharif* season, 2019 to study the influence of cropping geometry and *in situ* soil moisture conservation practices on growth and yield of upland rice and to work out the economics of cultivation.

Relevant details about the materials used, the methods followed and practices employed for the field experiment are briefly described.

3.1. MATERIALS

3.1.1. Experimental site

The field experiment was conducted at the Instructional farm, College of Agriculture, Vellayani, Kerala Agricultural University (KAU), Kerala. The farm is situated at 8.5^{o}N latitude and 76.9^{o}E longitude at an altitude of 29 m above the mean sea level with a typical warm humid tropical climate.

3. 1. 2. Soil

The soil of the experimental site was red sandy clay loam. The composite soil samples were taken from 0-15 cm depth, the physical and chemical characteristics of the soil are given in the Table 1.

3. 1. 3. Climate

The weather parameters were recorded for the standard weeks (24- 41) during the crop period and are furnished in Appendix I and Fig. 1.

The abstract of weather data is given in Table 1.

Table 1. The abstract of weather data during the experimental period

Weather element	**Range**	**Mean**
Maximum temperature (^{o}c)	28.6-32.6	30.6
Minimum temperature (^{o}c)	23.0-26.3	24.65
Rainfall (mm)	-----------	99.05
Maximum Relative humidity (%)	80-100	90
Minimum Relative humidity (%)	70-98	84
Weekly evaporation (mm)	0-4.6	2.3

3. 1. 4. Season

The field study was conducted in *kharif* season of 2019. The crop was sown on 14^{th} June, 2019 and harvested on 14^{th} October, 2019.

3. 1. 5. Crop variety

Rice: Aiswarya (PTB52) – a medium duration variety of 120-125 days, released from RARS (Regional Agricultural Research Station), Pattambi was used for the study. The grains are red long and bold type. Suitable for modan cultivation. It is resistant to blast and blight diseases and also resistant to pests like brown plant hopper. It is suited for both first and second crop seasons.

Cowpea: MFC-0814, released in 2012 by University of Agricultural Sciences, College of Agriculture, Mandya was used for the study. It is a superior variety in terms of green fodder and dry matter, resistant to rust and well adapted to South zone. It contains 22.46 % of crude protein.

3. 1. 6. Hydrogel

The hydrogel used in this study was Zeba Hydrogel, a starch - based superabsorbent polymer, which was invented and developed by a team of USDA chemists. In 2003, it was released by a foreign based company Absorbent Technologies Inc. Beaverton, Oregon, USA. Zeba hydrogel is a starch-based, superabsorbent polymer designed to keep constant supply of moisture available to germinating seed, seedlings, and plants throughout the growing season. Made from natural corn starch, each Zeba granule works like a sponge, absorbing in excess of 400 times its own weight of water, forming hydrogels that slowly release moisture back to plants as they need it.

Zeba also binds and releases water-soluble nutrients, keeping more fertilizer in the root zone where it can be used by plants, thus creating a healthy micro environment. Over time, Zeba is broken down and consumed by naturally occurring microorganisms in the soil, leaving no residue behind. With a steady supply of water and nutrients, plants grow healthier, crops are more uniform, and yields are increased. Zeba does not waterlog soil since it stops absorbing moisture when it reaches its water holding capacity, then slowly releases the precise amount of water as needed.

Rate and method of application: Hydrogel is applied @ 2.5 kg ha^{-1} along the seed rows by mixing with the soil. It is environmental friendly, biodegradable and active for about a period of 5 months in soil.

3. 1. 7. Coir pith Compost

Coir pith compost is a good source of organic manure for dry land agriculture as it can absorb water five times its weight and thereby increases the water holding capacity of soil. The advantages of coir pith compost over ordinary compost materials are it adds micronutrient to the soil, enhances microbial activity and reduces soil erosion. In addition to the higher moisture content, coir pith compost is known to supply micro and secondary nutrients such as magnesium, sulphur, calcium besides N, P and K. It also improves the physical and chemical properties of soil.

Rate and method of application: Coir pith compost is applied @ 2.5 t ha^{-1} and the method of application is broadcasting.

3. 1. 8. Source of Seed Material

Seeds of Aiswarya Rice variety were purchased from RARS (Regional Agricultural Research Station), Pattambi, Kerala.

Seeds of MFC-08-14 Cowpea variety were purchased from GKVK (Gandhi Krishi Vignan Kendra), University of Agricultural Sciences, Bangalore.

3. 1. 9. Source of Hydrogel

Zeba hydrogel used in this experiment was purchased from Farm house, Chenthitta, Thiruvananthapuram.

3. 1. 10. Source of Coir Pith Compost

Coir pith compost used in this experiment was purchased from Masra Kissan Kendra Agri Supermarket, Thiruvallam, Thiruvananthapuram.

3. 1. 11. Manures and Fertilizers

Well decomposed and dried FYM containing 0.5 per cent of N, 0.2 per cent of P_2O_5 and 0.5 per cent of K_2O was used for the experiment. The fertilizers used for the experiment were Urea (46 per cent N), Rajphos (20 percent P_2O_5) and Muriate of potash (60 per cent K_2O).

3.2. DESIGN AND LAYOUT

The treatment comprises two planting geometries and different *in situ* soil moisture conservation practices.

Design	:	RBD
Treatment	:	9
Replication	:	3
Plot size	:	5m x 4m
Variety	:	Aiswarya (PTB 52)
Season	:	Kharif, 2019

Border rows were left on all the sides to prevent border effects in each plot and five plants were selected from the net plot area randomly for observations. The layout the field experiment is given in Fig.2.

3.2.1 Treatments

T_1: Normal planting of upland rice (20 cm x 10 cm)

T_2: Normal planting with live mulching of cowpea

T_3: Normal planting with live mulching of cowpea and hydrogel application

T_4: Normal planting with live mulching of cowpea and coir pith compost application

T_5: Normal planting with live mulching of cowpea and hydrogel + coir pith compost application

T_6: Paired row planting with live mulching of cowpea

T_7: Paired row planting with live mulching of cowpea and hydrogel application

T_8: Paired row planting with live mulching of cowpea and coir pith compost application

T_9: Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application

Table 2. Physico-Chemical parameters of soil

Particulars	Content	Method used
A. Physical properties		
Bulk density (Mg m^{-3})	1.54	Undisturbed core sample (Black *et al.*, 1965)
Particle density (Mg m^{-3})	2.86	
Porosity (%)	46.00	
Soil Moisture Constants		
Field Capacity	16.38	Pressure plate apparatus (Gardner, 1955)
Permanent Wilting Point	10.42	
Particle Size Composition		
Coarse sand (%)	16.08	International pipette method (Piper, 1967)
Fine sand (%)	31.46	
Silt (%)	23.45	
Clay (%)	28.76	
Texture	Sandy clay loam	
B. Chemical composition		
pH	4.8	pH meter with glass electrode (Jackson, 1973)
Organic Carbon (%)	0.67	Chromic acid wet digestion method (Walkley and Black, 1934)
Available N (kg ha^{-1})	190.15	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	35.45	Bray extraction and photoelectric Colorimetry (Jackson, 1973)
Available K (kg ha^{-1})	248.12	Ammonium acetate method (Jackson, 1973)

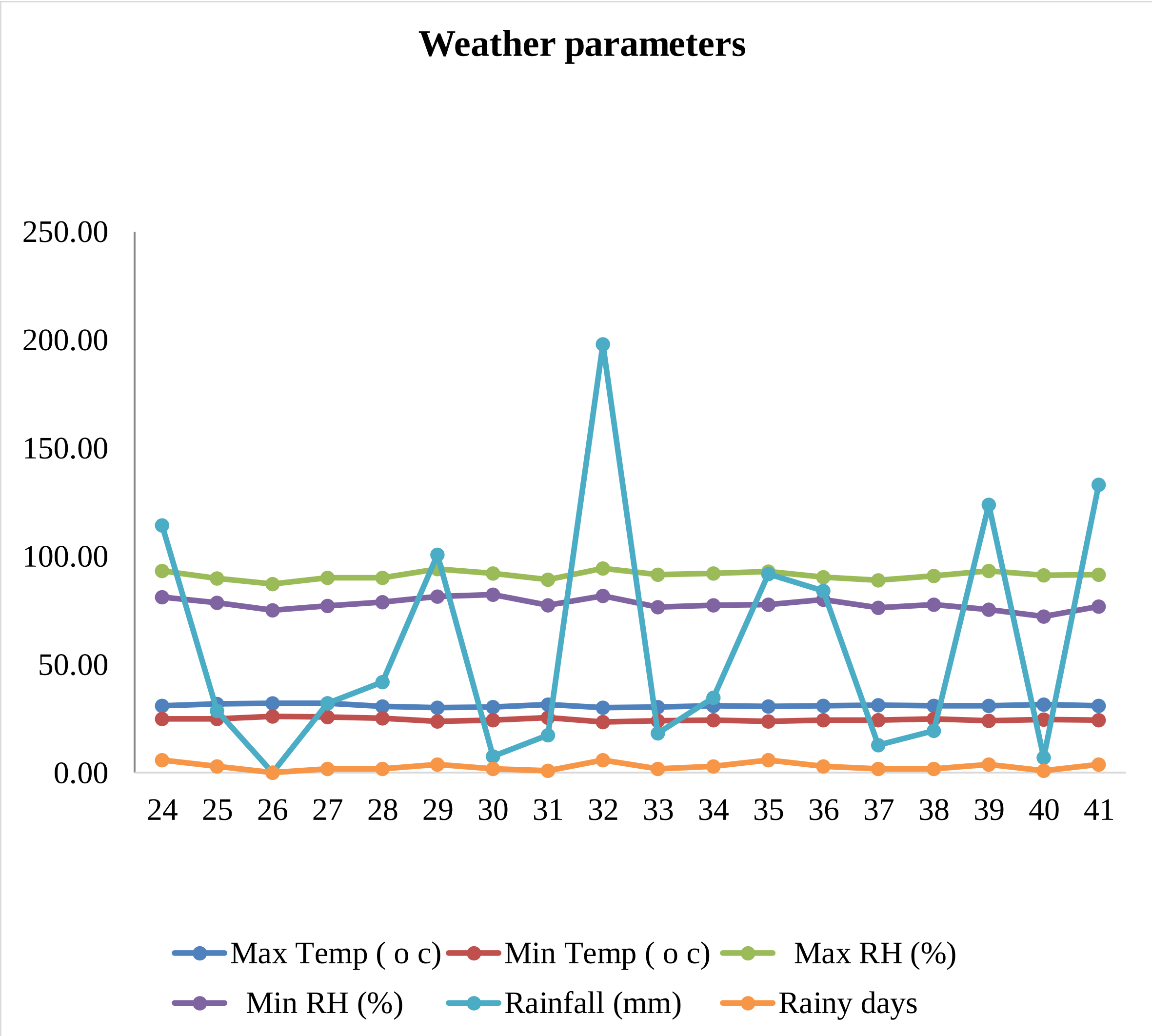


Fig. 1. Weather parameters during the crop season in standard week (June 14 to October 14, 2019).

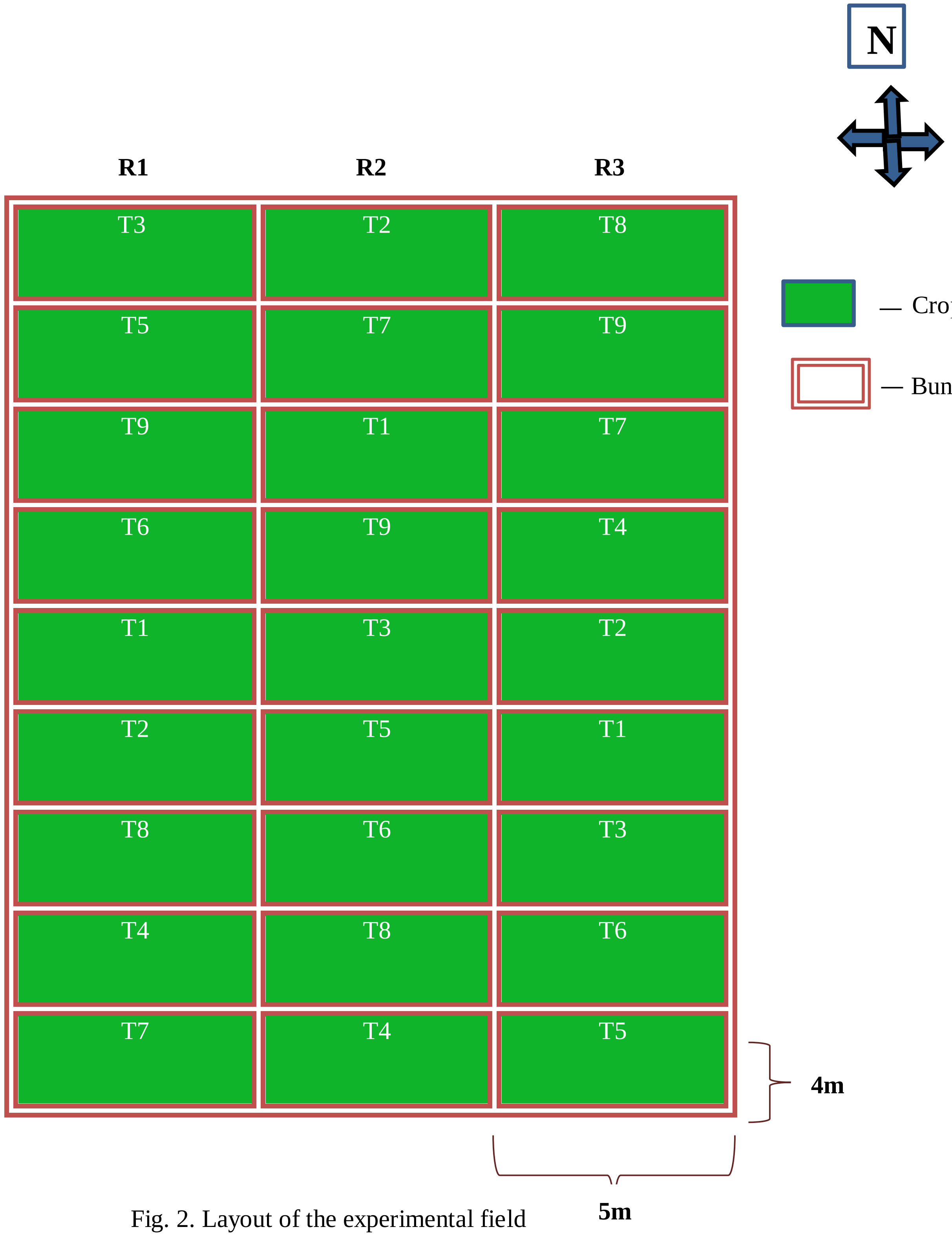


Fig. 2. Layout of the experimental field

Plate 1. General view of the experimental field

Plate 2.1. Seedling stage

Plate2.2. Tillering stage

Plate 2.3. Maturity stage

Plate 2.4. Harvesting stage

Plate 2. Different growth stages of upland rice

3.3. FIELD EXPERIMENT

3. 3. 1. Land Preparation

The entire land was ploughed uniformly and levelled by using a tiller. Stubbles of previous crop were removed and experimental plots were laid out. Before the start of layout, the composite soil samples were collected for analysis. Experimental plots of size 5m x 4m and bunds of 30 cm width were made on all the four sides of the plot.

3. 3. 2. Seeds and Sowing

Aiswarya seeds were dibbled at the rate of 80 kg ha^{-1}. For normal planting, a spacing of 20 cm x 10 cm was followed. For paired row planting, spacing was 10 cm x 10 cm with in paired row and two such paired rows were separated by a spacing of 40 cm, in order to maintain uniform plant population in both the crop geometries (Fig.3). In normal planting cowpea variety MFC -08-14 was sown in between two rows of rice and in paired row planting three rows of cowpea were planted between paired rows of rice.

3. 3. 3. Application of manures and fertilizers

Farmyard manure was applied uniformly to all the plots @ 5 t ha^{-1} and mixed well with the soil. The nutrients at the rate of 60 kg N, 30 kg P_2O_5, 30 kg K_2O ha^{-1} were applied as per Package of Practices recommendation of KAU (2016) for rice crop. Cowpea was not fertilised, used as a live mulch and incorporated at 45 DAS.

3. 3. 4. Thinning and Gap Filling

The seeds germinated within seven days after sowing. Thinning and gap filling operations were done at 15 DAS in order to maintain uniform population in all the plots at the rate of two seedlings $hill^{-1}$.

3. 3. 5. Water Management

Irrigation was given as per the need of crop during cropping period. At establishment stage of crop followed by critical stages, frequent irrigation was given.

3. 3. 6. Weed Management

One hand weeding was carried out at 20 DAS and a herbicide spray with Bispyribac sodium was given at 35 DAS to control the weeds on bunds.

3. 3.7. Plant Protection

To control sheath blight, Carbendazim (Bavistin 50 WP) @ 125 g a.i. ha^{-1} was applied to all the plots. To control rice stem borer Thiamethoxam 25% WG 100 g ha^{-1} was used. To control rice gundhi bug, two sprays of Malathion (750 ml ha^{-1}) were given at flowering and milking stage of the crop. No variation in the population of gundhi bug was observed under varied cropping geometry.

3. 3. 8. Plant Sampling

The plant samples were collected at 30, 60 and 90 DAS and finally at harvesting stage for biometric observations and chemical analysis.

3. 3. 9. Harvest

The crop was harvested at 120 DAS i.e., on October, 2019 when 80 percent of panicles were straw colored and grains in lower portion of panicle is in hard dough stage. The plants from net plot and border plants were harvested separately. Threshing was done manually and was cleaned to make the produce free from sticks, dust particles, chaffy grains, dried and weighed. Weight of straw and grain were expressed as kg ha^{-1}.

3.4. OBSERVATIONS

3. 4. 1. Observations on growth characters

3. 4. 1. 1. Plant height (30 DAS, 60 DAS, harvest)

The plant height was recorded from five plants selected randomly from each plot. The plant height was taken from base of the stem to the tip of top most leaf at 30, 60 DAS and during harvest and was measured.

3. 4. 1. 2. Number of tiller m^{-2} at 60 DAS

The tiller number m^{-2} was recorded from the net plot area of all the plots at 60 DAS and mean values were worked out and recorded.

3. 4. 1. 3. Leaf Area Index at 60 DAS

Five plants selected randomly from the net plot were tagged and the maximum length and breadth of third leaf from top were taken at 60 DAS. The total number of leaves are counted for each plant and multiplied with the mean value. Yoshida *et al.* (1976) suggested a formula for LAI.

$$LAI = K\ \frac{(L \times W) \times \text{Number of leaves hill}^{-1}}{\text{Land area occupied by the plant}}$$

Where, K – Constant factor (0.75)

L – Maximum length of 3rd leaf blade from the top (cm)

W – Maximum width of the leaf blade (cm)

3. 4. 1. 4. Dry Matter Production (DMP) (60 DAS, harvest)

At 60 DAS and harvest the observational plants were uprooted, washed, sun dried and oven dried at 70 $\pm$ 5^{o}c to constant weight and expressed in kg ha^{-1}.

3. 4. 2. Observations on yield attributes of rice

3. 4. 2. 1. Productive Tillers m^{-2}

From each plot, the number of productive tillers from one m^2 area were recorded at harvest and the mean values were computed accordingly.

3. 4. 2. 2. Length of Panicle

Panicle length of five tagged plants were measured from the point of scar to the tip of the panicle and mean panicle length was computed and expressed in cm.

3. 4. 2. 3. Grain weight Panicle^{-1}

The panicles collected for the measurement of panicle length were used for the determination of weight of panicle. The panicles were weighed using an electronic balance and mean value was worked out and expressed in g.

3. 4. 2. 4. Number of Spikelets panicle^{-1}

Five sample plants were taken from each plot and spikelets from each panicle were removed and counted and the mean value was worked out.

3. 4. 2. 5. Percentage of Filled Grains Panicle $^{-1}$

Five sample plants were taken from all the plots and from each panicle of plant the number of filled grains and total grains and were counted and recorded. The percentage of filled grains panicle $^{-1}$ can be computed by using the formula

$$\text{Percentage of Filled Grains Panicle}^{-1} = \frac{\text{Number of filled grains panicle}^{-1}}{\text{Total number of grains panicle}^{-1}}$$

3. 4. 2. 6. Thousand Grain Weight

From the five sample plants of each plot, thousand grains were separated from clean produce and the mean weight was expressed in g.

3. 4. 2. 7. Grain Yield ha^{-1}

From each plot the grains were harvested separately and dried in sun to a moisture content of 14 percent and its weight was recorded and expressed in kg ha^{-1}.

3. 4. 2. 8. Straw Yield $^{-1}$

The straw was harvested from each plot separately and dried in sun consecutively for three days and weight was recorded and expressed in kg ha^{-1}.

3. 4. 2. 9. Harvest Index

The harvest index was calculated by using the formula suggested by Donald and Hamblin (1976).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3. 4. 3. Physiological estimations

3. 4. 3. 1. Proline content at panicle initiation

Proline content of leaves was estimated by the method described by Bates *et al*. (1973) and expressed as µmol g^{-1} of fresh weight.

3. 4. 3. 2. Relative Leaf Water Content (LWC) at flowering stage

The method was proposed by Weatherley (1950) which was later modified by Slatyer and Barrs (1965) used to estimate RLWC at 30, 60 and 90 DAS and it was expressed in percentage.

$$RLWC = \frac{\text{Fresh weight} - \text{Dry weight X 100}}{\text{Turgid weight} - \text{Dry weight}}$$

3. 4. 3. 3. Chlorophyll content at panicle emergence stage

The Chlorophyll content was estimated by method prescribed by Reddy *et al*. (1992). The amount of pigments was calculated using the formula detailed below and expressed in mg g^{-1} of fresh weight.

$$\text{Chlorophyll a} = [\,12.7\ (\text{OD at } 663) - 2.69\ (\text{OD at } 645)] \times \frac{V}{W \times 1000}$$

$$\text{Chlorophyll b} = [\,22.9\ (\text{OD at } 645) - 4.68\ (\text{OD at } 663)] \times \frac{V}{W \times 1000}$$

$$\text{Total Chlorophyll} = [\,20.2\ (\text{OD at } 645) + 8.02\ (\text{OD at } 663)] \times \frac{V}{W \times 100}$$

Where OD – optical density, W – fresh weight of leaves, V – final volume of extract

3. 4. 4. Chemical estimations

3. 4. 4. 1. Plant analysis

3. 4. 4. 1. 1. N P K uptake by crop at harvest

The uptake of N P K by crop at harvest was estimated by multiplying the nutrient content of sample with respective dry weight of the sample which is to be expressed in kg ha^{-1}.

$$\text{Nutrient Uptake} = \frac{\text{Percentage of nutrient x Total dry matter production (kg ha}^{-1}\text{)}}{100}$$

3. 4. 4. 2. Soil analysis

3. 4. 4. 2. 1. N P K and Organic C before sowing and after harvest

The initial status of major nutrients N P K and organic C was estimated in the soil by collecting the composite soil samples before cultivation practices and the analysis of soil was done for its physico-chemical characteristics by using standard procedures.

After the conduct of experiment, the composite soil samples were collected from each plot separately at 15 cm depth and the soil analysis was done for N P K and organic C.

3. 4. 5. Root Parameters

3. 4. 5. 1. Root Shoot Ratio

Five sample plants were collected randomly from individual plots and the dry weights of root and shoot were recorded separately and root to shoot ratio was calculated.

3. 4. 5. 2. Root Length

Five sample plants were uprooted from each plot at harvest stage, root portion was separated carefully, cleaned and the length was measured. The mean value was worked and expressed in cm.

3. 4. 5. 3. Root Weight

Five sample plants were uprooted from each plot at harvest stage, root portion was separated carefully, cleaned and dried in a hot air oven at 70 $\pm$ 5^{o}c to constant weight at harvest stage and it is expressed in g.

3. 4. 5. 4. Root Volume

Root volume plant^{-1} was found out by displacement method (Misra and Ahmed, 1989) and expressed in cm^3 plant^{-1}.

3. 4. 6. Soil parameters

3. 4. 6. 1. Soil moisture content at 15 cm depth

Soil moisture content was estimated by using a standard moisture meter which was inserted at 15 cm soil depth in individual plots and the moisture content were recorded at sowing, 30, 60, 90 DAS and at harvest stage.

3. 4. 6. 2. Bulk Density

Physical properties such as bulk density and WHC were analysed before and after the experiment by collecting the undisturbed soil samples from top soil at 0-15 cm depth using core sampler (Gupta and Dakshinamoorthy, 1980).

$$\text{Bulk density (Mg m}^{-3}\text{)} = \frac{\text{Weight of soil solid (Mg)}}{\text{Total soil Volume (m}^3\text{)}}$$

3. 4. 6. 3. Soil Porosity

Porosity (%) = $(1 - D_b / D_p) \times 100$

Where, D_b is soil bulk density

D_p is soil particle density

3. 4. 7. Observation on weeds

3. 4. 7. 1. Weed composition and weed dry weight

Observations on weed composition and weed dry weight were recorded by the quadrat method. From individual plots, the weeds present within the quadrant were uprooted, cleaned, dried in air an oven at 75 $\pm$ 5^{o}c and dry weight was expressed in kg ha^{-1} at 42 DAS of cowpea.

3. 4. 8. Pest and Disease Incidence

The incidence of major pests and diseases were observed and recorded.

3. 4. 9. Economic Analysis

On the basis of prevailing input costs and market price of the produce (grain and straw), the cost of cultivation and economics were worked out for all the treatments.

3. 4. 9. 1. Gross Income ₹ ha^{-1}

Gross return was calculated on the basis of grain, straw yield and their existing market prices. The gross income is calculated by using the formula

Gross return (₹ ha^{-1}) = Grain yield (t ha^{-1}) x Market price (₹ t^{-1})

+ Straw yield (t ha^{-1}) x Market price (₹ t^{-1})

3. 4. 9. 2. Net Income ₹ ha^{-1}

Net income is the income obtained after subtraction of cost of cultivation (₹ ha^{-1}) from gross income (₹ ha^{-1}).

Net return (₹ ha^{-1}) = Gross return (₹ ha^{-1}) – Cost of cultivation (₹ ha^{-1})

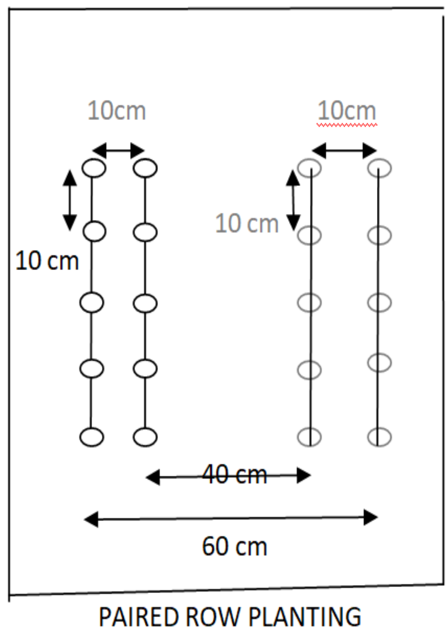
3. 4. 9. 3. Benefit Cost Ratio (BCR)

The benefit cost ratio (BCR) was worked out as follows

$$BCR = \frac{\text{Gross return (₹ ha}^{-1})}{\text{Cost of cultivation (₹ ha}^{-1})}$$

3. 4. 10. Statistical analysis

The data obtained from the experiment was analysed statistically as per the procedure given by Rangaswamy (1995). Wherever the significant differences were observed among the treatments, the critical difference values at 5 percent level of probability was worked out for comparison of means. The treatment effects which were not significant were designated as NS.



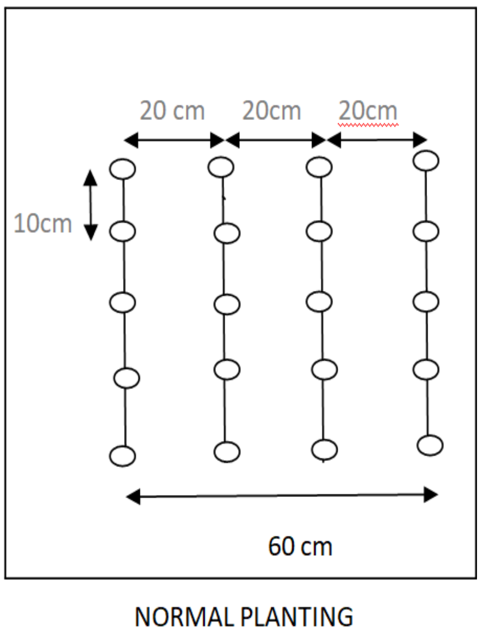


Fig.3 Cropping geometry

RESULTS

4. RESULTS

Data on various attributes were tabulated, analysed statistically and results are briefly presented.

4.1 GROWTH CHARACTERS

4.1.1 Plant Height (30 DAS, 60 DAS, Harvest)

The mean data on plant height at different growth stages viz., 30 DAS, 60 DAS and harvest are presented in Table 3.

At 30 DAS, there was no significant difference among treatments, while at later stages of growth, the treatments differed significantly.

At 60 DAS, the treatment T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application) produced the tallest plants (91.78 cm) and was on par with all treatments, except the treatment T_1 (Normal planting of upland rice), which produced the shortest plants (83.81 cm).

At harvest, the treatments differed significantly and T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) produced the tallest plants (109.13 cm) and was significantly superior to the rest of the treatments. The next best treatment was T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application) with a plant height of 104 cm and was on par with T_3, T_4, T_7 and T_8. The treatment T_1 (Normal planting of upland rice) produced the shortest plants of 92.61 cm.

4.1.2 Number of Tillers m^{-2} at 60 DAS

The data on tiller number m^{-2} at 60 DAS are presented in Table 4.

At 60 DAS, the treatments showed significant difference and T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) resulted in the maximum tiller number (350) and was on par with T_5, T_4, T_3 and T_8. The lowest tiller number of 298 was recorded by the treatment T_1 (Normal planting of upland rice).

Table 3. Effect of cropping geometry and *in situ* soil moisture conservation practices on plant height at different growth stages, cm.

Treatments	30 DAS	60 DAS	Harvest
T_1	58.81	83.81	92.61
T_2	59.69	88.86	99.81
T_3	58.53	88.79	100.60
T_4	58.70	90.78	102.16
T_5	58.56	91.78	104.00
T_6	58.88	90.65	98.91
T_7	59.46	90.54	100.73
T_8	59.13	90.70	101.09
T_9	59.41	91.32	109.13
SEm (±)	0.67	1.04	1.29
CD (0.05)	NS	3.150	3.897

Table 4. Effect of cropping geometry and *in situ* soil moisture conservation practices on number of tillers m^{-2} and leaf area index (LAI) at 60 DAS

Treatments	Number of Tillers m^{-2}	Leaf Area Index (LAI)
T_1	298.00	3.93
T_2	325.00	4.19
T_3	337.00	4.13
T_4	335.00	4.18
T_5	349.33	4.22
T_6	313.00	4.25
T_7	314.33	4.15
T_8	331.00	4.22
T_9	350.00	4.34
SEm (±)	6.88	0.07
CD (0.05)	20.804	NS

4.1.3 Leaf Area Index (LAI) at 60 DAS

The results of LAI at 60 DAS (Table 4.) revealed no significant variation among treatments. Though not significant, the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) produced the highest LAI of 4.34. The lowest leaf area index (3.93) was recorded by T_1 (Normal planting of upland rice).

4.1.4 Dry Matter Production (DMP) (60 DAS, Harvest)

The results of dry matter production are given in Table 5.

The highest dry matter production (2464 kg ha^{-1}) at 60 DAS was recorded by the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) and was on par with the treatment T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application). The treatment T_8 was the next best treatment, which recorded the dry matter production of 2242 kg ha^{-1} and was on par with the treatments T_7, T_4, T_6, T_3 and T_2. The treatment T_1 resulted in the lowest dry matter production (1967 kg ha^{-1}).

The maximum dry matter production (5546 kg ha^{-1}) at harvest was recorded by the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) and was on par with the treatment T_5, T_7 and T_8. The treatment T_4 was the next best treatment, which recorded the dry matter production (4992 kg ha^{-1}) and was on par with the treatments T_6, T_3 and T_2. The treatment T_1 resulted in the lowest dry matter production (4276 kg ha^{-1}).

4.2 YIELD ATTRIBUTES AND YIELD

4.2.1 Productive Tillers m^{-2}

The mean data on productive tillers m^{-2} are presented in Table 6.

The statistical analysis of data revealed significant difference among treatments and T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) produced highest productive tillers (319) and was on par with T_5, T_2, T_7, T_3, T_4, T_8 and significantly superior to T_1 and T_6.

4.2.2 Length of Panicle

The data on length of panicle are given in Table 6.

The perusal of data revealed significant difference among treatments. The

Table 5. Effect of cropping geometry and *in situ* soil moisture conservation practices on dry matter production (DMP) (60 DAS and harvest), kg ha^{-1}

Treatments	60 DAS	Harvest
T_1	1967	4276
T_2	2124	4850
T_3	2138	4925
T_4	2220	4992
T_5	2399	5503
T_6	2143	4762
T_7	2237	5466
T_8	2242	5149
T_9	2464	5546
SEm (±)	60	174
CD (0.05)	182.6	525.4

treatment T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application) registered the maximum panicle length (25.29 cm) and was on par with T_9, T_4 and T_3 and significantly superior to the rest of the treatments. The shortest panicle (21.27 cm) was produced by T_1 (Normal planting of upland rice).

4.2.3 Grain Weight Panicle^{-1}

The data on grain weight panicle^{-1} are given in Table 6.

The treatments differed significantly and T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) registered the maximum grain weight (3.28 g) and was on par with all treatments, except T_6 and T_1. The lowest grain weight (2.84 g) was produced by T_1 (Normal planting of upland rice).

4.2.4 Number of Spikelets Panicle^{-1}

The data on number of spikelets panicle^{-1} are given in Table 7.

There was significant difference among treatments and T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) produced the maximum number of spikelets panicle^{-1} (141.00) and was on par with T_8, T_5 and T_4 and superior to the rest of the treatments. The lowest value (126.00) was recorded by T_1.

4.2.5 Percentage of Filled Grains Panicle^{-1}

The data on Percentage of filled grains panicle^{-1} are presented in Table 7.

The treatments differed significantly and T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application) resulted in the maximum value of 89.46 per cent and was on par with T_9 and T_8 and superior to rest of the treatments. The lowest value (80.77%) was recorded by T_1 (Normal planting of upland rice).

4.2.6 1000 Grain Weight

The data on 1000 grain weight are given in Table 7.

The statistical analysis of the data revealed that there was a significant difference among the treatments and the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) resulted in the highest 1000 grain weight (26.38 g) which was on par with the treatments T_5 and T_4.

Table 6. Effect of cropping geometry and *in situ* soil moisture conservation practices on productive tillers m^{-2}, length of panicle and grain weight $panicle^{-1}$.

Treatments	Productive tillers m^{-2}	Length of panicle (cm)	Grain weight $panicle^{-1}$ (g)
T_1	291.00	21.27	2.84
T_2	310.00	21.96	3.08
T_3	315.00	24.23	3.14
T_4	313.00	24.39	3.20
T_5	318.00	25.29	3.24
T_6	291.00	22.69	3.04
T_7	311.00	23.19	3.12
T_8	316.00	23.21	3.22
T_9	319.00	25.01	3.28
SEm (±)	3.48	0.56	0.07
CD (0.05)	10.517	1.684	0.217

Table 7. Effect of cropping geometry and *in situ* soil moisture conservation practices on number of spikelets panicle^{-1}, percentage of filled grains panicle^{-1} and 1000 grain weight

Treatments	Number of spikelets panicle^{-1}	Percentage of filled grains panicle^{-1}	1000 grain weight (g)
T_1	126.00	80.77	24.71
T_2	131.00	83.12	25.58
T_3	134.00	83.62	25.54
T_4	137.00	85.31	25.74
T_5	139.00	89.46	26.21
T_6	132.00	83.00	25.45
T_7	134.00	85.24	25.67
T_8	140.00	86.02	25.61
T_9	141.00	88.64	26.38
SEm (±)	1.79	1.18	0.24
CD (0.05)	5.412	3.576	0.689

The next best treatment was T_7, which was on par with T_8, T_6, T_2 and T_3. The treatment T_1 recorded the lowest 1000 grain weight (24.71 g).

4.2.7 Grain Yield ha^{-1}

The data on grain yield (Table 8) showed significant difference among treatments. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) resulted in the maximum grain yield (3825 kg ha^{-1}) and was significantly superior to rest of the treatments. The treatment T_5(Normal planting with live mulching of cowpea and hydrogel + coir pith compost application) was the second best treatment recording 3581 kg ha^{-1} and superior to rest of the treatments. The treatment T_1 (Normal planting of upland rice) produced the lowest grain yield (2374 kg ha^{-1}).

4.2.7 Straw Yield ha^{-1}

The data on straw yield is presented in Table 8.

The statistical analysis of data revealed that the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) produced the maximum straw yield (7670 kg ha^{-1}), which was on par with the treatment T_5 and significantly superior to rest of the treatments. The next highest straw yield was produced by the treatment T_7 (Paired row planting with live mulching of cowpea and hydrogel application) (6944 kg ha^{-1}), which was on par with the treatment T_8. The treatment T_2 produced straw yield of 6522 kg ha^{-1} and was on par with the treatments T_3 and T_4. The treatment T_6 recorded straw yield of 6100 kg ha^{-1} and the lowest straw yield of 5800 kg ha^{-1} was recorded by the treatment T_1 (Normal planting of upland rice).

4.2.8 Harvest Index

The data on harvest index (Table 8) revealed the highest value of 0.48 for treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) and was on par with the treatments T_3, T_5, T_7, T_8 and T_2.

Table 8. Effect of cropping geometry and *in situ* soil moisture conservation practices on grain yield, straw yield and harvest index

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index
T_1	2374	5800	0.42
T_2	2874	6522	0.46
T_3	2956	6489	0.47
T_4	3093	6389	0.45
T_5	3581	7667	0.47
T_6	2737	6100	0.45
T_7	3274	6944	0.47
T_8	3296	6867	0.47
T_9	3825	7700	0.48
SEm (±)	58	115	0.01
CD (0.05)	173.9	348.7	0.028

The treatment T_1 (Normal planting of upland rice) resulted in the lowest harvest index (0.42).

4.3 PHYSIOLOGICAL ESTIMATIONS

4.3.1 Proline Content at Panicle Initiation

The mean data on the proline content at panicle initiation is given in Table 9.

There was no significant difference among the treatments. Though not significant, the treatment T_1 (Normal planting of upland rice) resulted in the highest proline content of 0.49 μ mol g^{-1} FW. The lowest proline content of 0.43 μ mol g^{-1} FW was recorded by the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application).

4.3.2 Relative Leaf Water Content at Flowering Stage

The data on relative leaf water content is presented (Table 9).

The statistical analysis of the data showed pronounced difference among the treatments. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) showed the maximum relative leaf water content (80.61 %) and was on par with the treatments T_5 and T_8. The treatment T_7 showed the next highest relative leaf water content (77.61 %), which was on par with the treatments T_4 and T_3. The lowest value was registered by the treatment T_1 (Normal planting of upland rice) (73.96%).

4.3.3 Chlorophyll Content at Panicle Emergence Stage

The mean values of chlorophyll content are presented in the Table 9.

The data on statistical analysis did not show significant difference among the treatments. However, the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) had recorded the highest chlorophyll content of 1.02 mg g^{-1} FW.

Table 9. Effect of cropping geometry and *in situ* soil moisture conservation practices on physiological estimations

Treatments	Proline content at panicle initiation (µ mol g^{-1} FW)	Relative leaf water content at flowering stage (%)	Cholorophyll content at panicle emergence stage (mg g^{-1} FW)
T_1	0.49	73.96	1.00
T_2	0.49	74.61	1.00
T_3	0.48	76.42	1.01
T_4	0.47	77.09	1.01
T_5	0.45	80.34	1.01
T_6	0.47	74.45	1.00
T_7	0.48	77.61	1.00
T_8	0.44	79.00	1.00
T_9	0.43	80.61	1.02
SEm (±)	0.02	0.62	0.01
CD (0.05)	NS	1.878	NS

4.4 CHEMICAL ESTIMATIONS

4.4.1 Nitrogen Uptake by the crop at harvest

The mean data on N uptake as influenced by the treatments are given in Table 10.

The treatments differed significantly. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) had the highest N uptake of 68.92 kg ha^{-1} and was on par with the treatment T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application). The lowest N uptake of 50.65 kg ha^{-1} was recorded by the treatment T_1 (Normal planting of upland rice).

4.4.2 Phosphorus Uptake by the crop at harvest

The mean data on P uptake as influenced by the treatments are given in Table 10.

The treatments differed significantly. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) had recorded the highest P uptake of 16.63 kg ha^{-1} and was significantly superior to rest of the treatments. The lowest P uptake of 8.76 kg ha^{-1} was produced by the treatment T_1 (Normal planting of upland rice).

4.4.3 Potassium Uptake by the crop at harvest

The mean data on K uptake as influenced by the treatments are given in Table 10.

The treatments differed significantly. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) resulted in the highest K uptake of 60.95 kg ha^{-1} and was superior to the rest of the treatments. The lowest K uptake of 47.29 kg ha^{-1} was recorded by the treatment T_1 (Normal planting of upland rice).

4.4.4 Available Nitrogen

The mean data on available N as influenced by the treatments are presented (Table 11).

The treatments differed significantly. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) resulted in the highest available N of 214.20 kg ha^{-1} and was on par with the treatment T_5

(Normal planting with live mulching of cowpea and hydrogel + coir pith compost application). The lowest available N of 194.44 kg ha^{-1} was recorded by the treatment T_1 (Normal planting of upland rice).

4.4.5 Available Phosphorus

The mean data on available P as influenced by the treatments are given (Table 11).

The treatments differed significantly. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) resulted in the highest available P of 40.68 kg ha^{-1} and was on par with the rest of treatments, except T_1 and T_2. The lowest available P of 38.22 kg ha^{-1} was recorded in the treatment T_1 (Normal planting of upland rice).

4.4.6 Available Potassium

The mean data on available K as influenced by the treatments are presented (Table 11).

The treatments differed significantly. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) resulted in the highest available K of 266.76 kg ha^{-1} and was on par with the rest of the treatments except T_1 and T_2. The lowest available K of 250.95 kg ha^{-1} was recorded by the treatment T_1 (Normal planting of upland rice).

4.4.7 Soil Organic Carbon

The mean data on soil organic carbon as influenced by the treatments are given (Table 11).

The treatments showed no significant difference. However, the treatments T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application), T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application) and T_8(Paired row planting with live mulching of cowpea and coir pith compost application) had recorded the highest soil organic carbon of 0.70% and the lowest soil organic carbon of 0.68% was recorded in the treatment T_1 (Normal planting of upland rice).

Table 10. Effect of cropping geometry and *in situ* soil moisture conservation practices on N, P, K uptake by the crop at harvest, kg ha^{-1}

Treatments	N uptake	P uptake	K uptake
T_1	50.65	8.76	47.29
T_2	55.01	10.37	52.44
T_3	58.36	11.95	54.65
T_4	62.83	14.16	57.11
T_5	67.59	16.03	59.45
T_6	56.71	11.05	55.50
T_7	61.53	13.27	57.74
T_8	64.96	15.13	58.53
T_9	68.92	16.63	60.95
SEm (±)	0.79	0.18	0.49
CD (0.05)	2.382	0.541	1.482

Table 11. Effect of cropping geometry and *in situ* soil moisture conservation practices on available N, P, K and organic C after harvest

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Organic Carbon (%)
T_1	194.44	38.22	250.95	0.68
T_2	208.02	38.51	251.40	0.69
T_3	209.22	39.92	262.10	0.69
T_4	210.45	40.23	263.31	0.69
T_5	213.84	40.46	266.61	0.70
T_6	208.08	39.68	261.79	0.68
T_7	209.62	39.82	262.03	0.69
T_8	209.96	40.14	263.33	0.70
T_9	214.20	40.68	266.76	0.70
SEm (±)	0.62	0.51	2.85	0.01
CD (0.05)	1.880	1.545	8.621	NS

4.5 ROOT PARAMETERS

4.5.1 Root Shoot Ratio

The mean data on root shoot ratio at harvest was documented and furnished in Table 12.

The treatments had no significant difference. However, the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) and T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application) showed the highest value of 0.27 and the lowest value of 0.19 was recorded in the treatment T_1 (Normal planting of upland rice).

4.5.2 Root Length

The mean data on root length at harvest was documented, expressed in cm and furnished in Table 12.

The treatments significantly influenced the root length, the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) showed the maximum root length of 14.96 cm and was on par with the treatment T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application). The lowest root length of 11.01 cm was produced by the treatment T_1 (Normal planting of upland rice).

4.5.3 Root Weight

The mean data on root weight at harvest was documented, expressed in g and furnished in Table 12.

The treatments showed no significant difference. However, the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) showed the highest root weight of 3.63 g and the lowest root weight of 2.09 g was produced by the treatment T_1 (Normal planting of upland rice).

4.5.4 Root Volume

The mean data on root volume at harvest was documented, expressed in cm^3 and furnished in Table 12.

The treatments had no significant difference. However, the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) showed the highest root volume of 8.11 cm^3 and the lowest root volume of 7.75 cm^3 was recorded by the treatment T_1 (Normal planting of upland rice).

Table 12. Effect of cropping geometry and *in situ* soil moisture conservation practices on root parameters

Treatments	Root shoot ratio	Root length (cm)	Root weight (g)	Root volume (cm^3)
T_1	0.19	11.01	2.09	7.75
T_2	0.21	11.53	2.46	7.87
T_3	0.22	12.79	2.47	7.85
T_4	0.22	13.84	2.86	8.07
T_5	0.27	14.65	3.55	8.06
T_6	0.22	12.37	2.79	7.73
T_7	0.24	13.34	3.10	7.84
T_8	0.26	13.69	3.61	8.00
T_9	0.27	14.96	3.63	8.11
SEm (±)	0.01	0.21	0.09	0.16
CD (0.05)	NS	0.620	NS	NS

4.6 SOIL PARAMETERS

4.6.1 Soil Moisture Content at 15 cm depth

The mean data on soil moisture content at 15 cm depth was documented at 45 DAS, 60 DAS and harvest, expressed in % and furnished in Table 13.

At 45 DAS, there was no significant difference among treatments on soil moisture content, while at later stages of growth, the treatments differed significantly.

At 60 DAS, the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) showed the highest soil moisture content of 28.49% at 15 cm depth and was on par with the treatment T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application). The treatment T_1 (Normal planting of upland rice) showed the lowest moisture content of 21.32%.

At harvest, the treatments differed significantly and the treatment T_9 (Paired row planting with live mulching of cowpea, hydrogel and coir pith compost application) had recorded the highest soil moisture content of 29.12% and was on par with the treatments T_5, T_7 and T_3. The treatment T_1 (Normal planting of upland rice) had recorded the lowest moisture content of 19.22%.

4.6.2 Bulk Density

The mean data on bulk density after harvest was documented, expressed in Mg m^{-3} and furnished in Table 14.

The results revealed that there was no significant difference among treatments. However, highest bulk density of 1.45 Mg m^{-3} was recorded in the treatment T_1 (Normal planting of upland rice) and the lowest bulk density of 1.42 Mg m^{-3} were recorded in the treatments T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application), T_8 (Paired row planting with live mulching of cowpea and coir pith compost application) and T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application).

4.6.3 Porosity

The mean data on porosity after harvest was documented, expressed in % and furnished in Table 14.

The treatments showed no significant difference. However, highest porosity of 44.75% was recorded in the treatment T_9 (Paired row planting with live mulching of

Table 13. Effect of cropping geometry and *in situ* soil moisture conservation practices on soil moisture content at 15 cm depth

Treatments	Soil moisture content at 15 cm depth (%)		
	45 DAS	60 DAS	Harvest
T_1	19.20	21.32	19.22
T_2	23.52	24.68	25.80
T_3	26.50	24.99	27.94
T_4	25.34	27.15	26.96
T_5	27.01	28.22	28.41
T_6	24.52	25.39	25.24
T_7	26.74	26.23	28.19
T_8	25.71	25.75	27.00
T_9	27.05	28.49	29.12
SEm (±)	0.33	0.41	0.46
CD (0.05)	NS	1.248	1.388

Table 14. Effect of cropping geometry and *in situ* soil moisture conservation practices on soil parameters

Treatments	Bulk density (Mg m^{-3})	Porosity (%)
T_1	1.45	43.58
T_2	1.43	43.62
T_3	1.44	43.80
T_4	1.43	43.83
T_5	1.42	44.08
T_6	1.44	43.77
T_7	1.43	43.83
T_8	1.42	44.26
T_9	1.42	44.75
SEm (±)	0.01	0.23
CD (0.05)	NS	NS

cowpea and hydrogel + coir pith compost application) and the lowest porosity of 43.58 was recorded in the treatment T_1 (Normal planting of upland rice).

4.7 OBSERVATIONS ON MAJOR WEEDS OF UPLAND RICE

4.7.1 Weed Composition

The important grass weeds observed were *Echinochloa colona, cynodon dactylon, Dactyloctenium aegyptium.* Among the sedges, *Cyperus rotundus* was observed. The broad leaved weeds like *Phyllanthus niruri, Alternanthera sessilis, Mimosa pudica* were also observed.

4.7.2 Weed Dry Weight m^{-2}

The data on weed dry weight m^{-2} after cowpea harvest was recorded, expressed in g m^{-2} and furnished in Table 15.

The results revealed significant difference among treatments. The treatment T_1 (Normal planting of upland rice) showed significantly the highest weed dry weight of 15.82 g m^{-2}. The lowest weed dry weight of 6.19 g m^{-2} was recorded in the treatment T_7 (Paired row planting with live mulching of cowpea and hydrogel application) and was on par with all other treatments except T_3.

4.8 PEST AND DISEASE INCIDENCE OF RICE

The major pest observed in the field was rice gundhi bug. The important diseases observed were grain discoloration and blight. The incidence of pests and diseases never reached the threshold level and hence uniform score was given to all the plots in field.

4.9 ECONOMIC ANALYSIS

4.9.1 Net income

The mean data pertaining to the effect of cropping geometry and *in situ* soil moisture conservation practices on net income were calculated, expressed in ₹ ha^{-1} and presented in Table 16.

The results revealed significant difference among treatments. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) resulted the highest net income of 62,887 ₹ ha^{-1} was on par with the treatment T_7 and significantly superior to rest of the treatments. The lowest net income of 36,803 ₹ ha^{-1} was worked out in the treatment T_1 (Normal planting of upland rice).

4.9.1 BC Ratio

The mean data pertaining to the effect of cropping geometry and *in situ* soil moisture conservation practices on benefit cost ratio were calculated and presented in Table 16.

The results revealed significant difference among treatments. The treatment T_7 (Paired row planting with live mulching of cowpea and hydrogel application) showed the maximum BC ratio of 1.84 and was on par with the treatment T_9. The lowest BC ratio of 1.45 was recorded in the treatment T_4 (Normal planting with live mulching of cowpea and coir pith compost application).

Table 15. Effect of cropping geometry and *in situ* soil moisture conservation practices on weed dry weight, g m^{-2}

Treatments	Weed dry weight
T_1	15.82
T_2	6.87
T_3	7.10
T_4	6.84
T_5	6.42
T_6	6.81
T_7	6.19
T_8	6.42
T_9	6.34
SEm (±)	0.28
CD (0.05)	0.847

Table 16. Effect of cropping geometry and *in situ* soil moisture conservation practices on economic analysis

Treatments	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	BC ratio
T_1	94963	36803	1.63
T_2	114963	45288	1.65
T_3	118222	47172	1.66
T_4	123703	38528	1.45
T_5	143259	53109	1.59
T_6	109480	39805	1.57
T_7	130963	59913	1.84
T_8	131851	43676	1.50
T_9	153037	62887	1.80
SEm (±)		2301	0.03
CD (0.05)		6958.2	0.098

DISCUSSION

5. DISCUSSION

The results of the field trial entitled "Cropping geometry and *in situ* soil moisture conservation practices on upland rice (*Oryza sativa* L.)" are briefly discussed in this chapter.

5.1 GROWTH CHARACTERS

Paired row planting of upland rice (with one paired row spaced at 10 cm and two such pairs of rows at 40 cm) as given in Figure 3 combined with live mulching of cowpea, hydrogel and coir pith compost application favourably influenced the growth characters.

Plant height at 60 DAS and harvest were profoundly influenced by cropping geometry and *in situ* soil moisture conservation practices, while at 30 DAS the treatments did not have any significant influence on plant height (Table 3 and Fig. 4). There is progressive increase in plant height in all treatments as the crop advances to maturity. Cropping geometry is an important factor determining the growth characters of upland rice (Sakariyawo *et al.,* 2014). At 60 DAS and harvest, paired row planting of upland rice combined with *in situ* moisture conservation practices viz., live mulching of cowpea grown in the interspaces (40 cm) of the paired rows, application of coir pith compost and hydrogel significantly influenced plant height. Rice under paired row system produced taller plants for better interception of solar radiation, to reduce competition for resources to the minimum and other complementary effects as evident from Table 3. Without compromising the plant population, modifying the planting geometry of upland rice for live mulching will have complementary effect on growth by way of reducing evaporation, conserving moisture, improving soil physical properties, fertility status and suppressing weeds. This is in conformity with the findings of Thavaprakash, (2005) and Bezbaruha *et al.* (2011). In normal planting of upland rice at 20 cm x 10 cm, one row of cowpea is intercropped after every row of rice which resulted in more competition for nutrients, light, moisture and cowpea overgrew and masked upland rice preventing its further growth. Live mulching of cowpea and its subsequent incorporation into the soil might have improved the soil nitrogen, organic matter, moisture, smothered weeds and all these complementary effects helped the rice plant to grow tall. This beneficial effect of cowpea led to the superiority of the treatment T_9 over other treatments in terms of plant height (Table 3). Live mulching of cowpea and its subsequent incorporation is one of the good organic sources of nitrogen besides increasing the nitrogen use efficiency. This corroborates with the findings of Okonji *et al.* (2011), Aparna (2018) and Langangmeilu (2019). Application of hydrogel in treatment T_9 improved the soil moisture status and water uptake by the crop. Water uptake is the first important event after sowing of seeds in the soil. A soil with optimum moisture contents is a good medium for seeds to germinate. Poor soil moisture level is one of the important reasons causing destitution of crop establishment. Higher soil moisture content with hydrogel enable the plant to put forth good growth in terms of height as evident from Table 3. It is well documented that the addition of gel-polymers has the potential to improve plant vegetative growth by retaining more moisture contents (Choudhary *et al.*, 1995; Al-Harbi *et al.*, 1999). Akhter *et al.* (2004) reported that the hydrogel addition in soil was effective in improving soil moisture availability and thus increased plant establishment. The higher moisture retention capacity of coir pith compost and subsequent slow release of moisture to crop are the salient characteristics highlighting the supremacy of coir pith compost in conservation farming. Moreover, it improved the soil physical properties and thereby favourably influenced the rice plant to absorb water and retain it for a long period. This is in conformity with the findings of Kandiannan, (1988). The beneficial effect of combined application of green manure cowpea raised in 40 cm interspace of paired rows of upland rice along with hydrogel and coir pith compost application in conserving soil moisture, improving soil nutrient status and soil physical properties led to the higher plant height in treatment T_9 over other treatments.

Cropping geometry combined with *in situ* soil moisture conservation practices favourably influenced the tiller number m^{-2} in upland rice as evident in Table 4 and Fig. 5. Paired row planting resulted in increased number of tillers compared to normal planting. This might be due to the wider spacing between the paired rows which supplied sufficient light, moisture, nutrients and helped in higher production of tillers and their subsequent growth in rice plant. In normal planting of rice at 20cm x 10cm spacing since one row of cowpea is intercropped after every row of rice, cowpea overgrew rice and competed for resources which might have adversely affected tiller production in upland rice. Similar findings were reported by Shrirame *et al.* (2000) in rice. Live mulching of cowpea between paired rows reduced the evaporation losses thereby improved the moisture availability and also reduced the weed growth which helped in better utilisation of resources and hence increased tiller number as observed from Table 4. The favourable effect of green manure cowpea on tillering in upland rice was reported by Aparna (2018) and Langangmeilu (2019). Application of hydrogel had a significant influence on increasing tiller number by absorbing moisture from soil and releasing slowly based on crop need and thereby improving water use efficiency as evident from Table 4. This corroborates with the findings of Rehman *et al.* (2011) in aerobic rice who reported that increased water holding capacity of hydrogel and its subsequent release helped the crop for producing more tillers. Application of coir pith compost increased P availability which improved the physiological functions such as cell division, albumin formation, root development and favoured tiller formation (Table 4) Munda *et al.* (1983), Ramesh *et al.* (2006).

The results in Table 5 and Fig.6 revealed that total dry matter production of upland rice was significantly influenced by the planting geometry along with live mulching of cowpea, hydrogel and coir pith compost application. Paired row planting resulted in increased dry matter production compared to normal planting. Increased availability of resources such as water, nutrients and solar radiation in paired row system might have helped the plant to put forth good growth in terms of plant height and tiller number and this reflected in higher dry matter production. This corroborates with the results of Dutta (2006), Mehta *et al.* (2012). Live mulching with cowpea reported increase in dry matter production due to continuous supply and slow release of nutrients through organic matter decomposition which aided in production of assimilates. Live mulching with cowpea conserved soil moisture, improved the growth attributes resulting in enhanced translocation of photosynthates from source to sink resulting in higher dry matter production as evident from Table 5. This is in conformity with the findings of Hemalatha *et al.* (2000), Aparna (2018), Langangmeilu (2019) in rice. The enhanced moisture conservation and N addition from the mulched biomass might have improved nutrient supply, and thus resulted in better growth and dry matter production as reported by Sharma *et al.* (2010). Total dry matter production depends on photosynthetic ability which is decided by leaf area, plant height and number of tillers. Hydrogel application not only improved plant height, tiller number but also enhanced the overall crop growth rate and dry matter in treatment T_9.

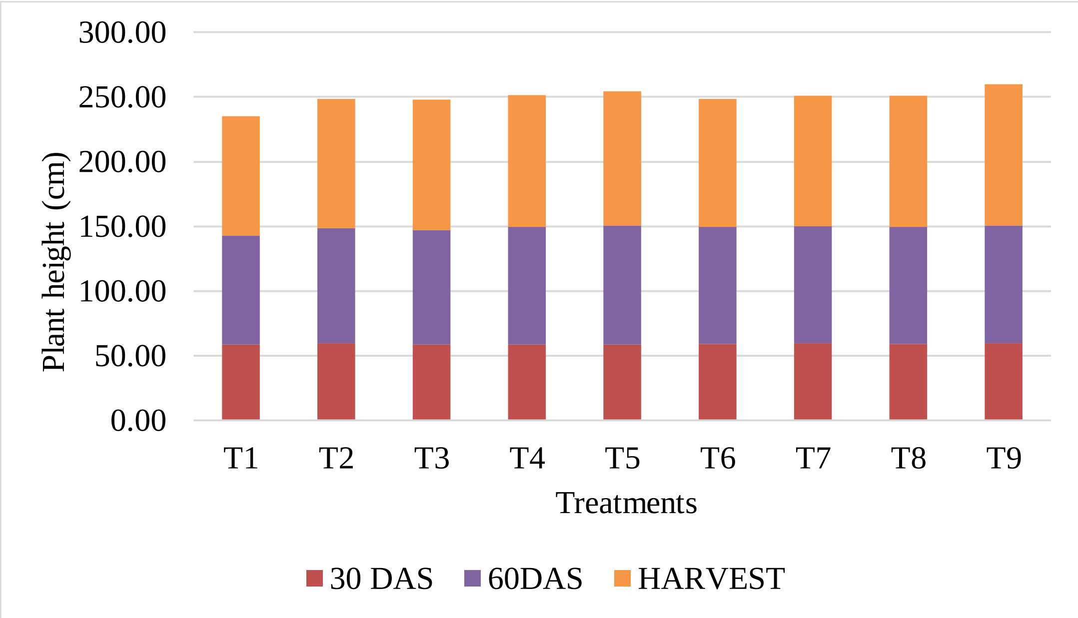


Fig. 4. Effect of cropping geometry and *in situ* soil moisture conservation practices on plant height at different growth stages, cm.

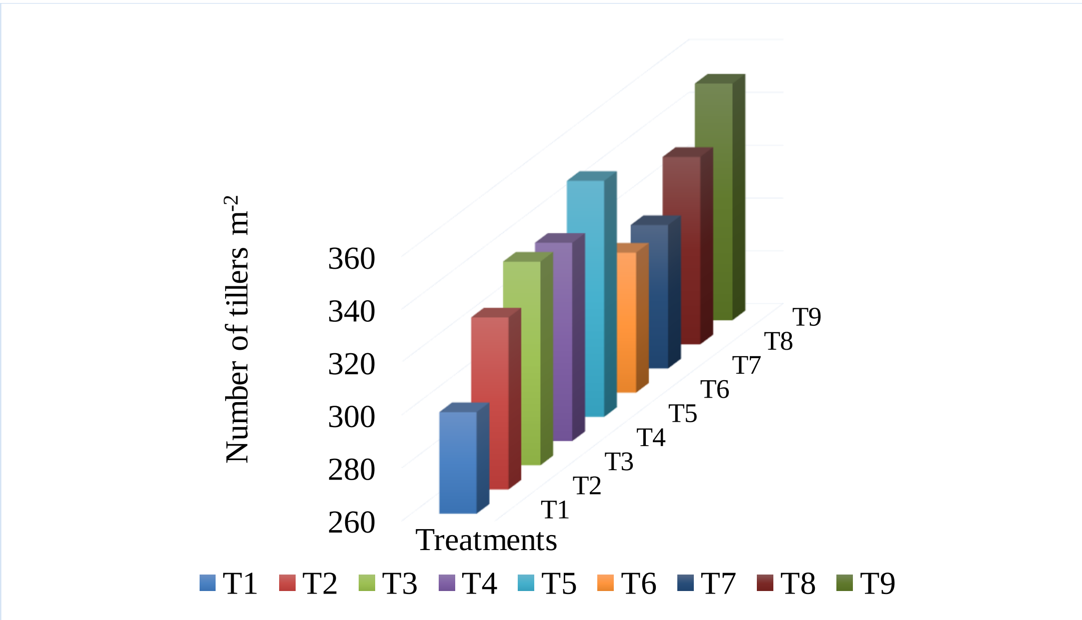


Fig. 5. Effect of cropping geometry and *in situ* soil moisture conservation practices on number of tillers m^{-2} at 60 DAS.

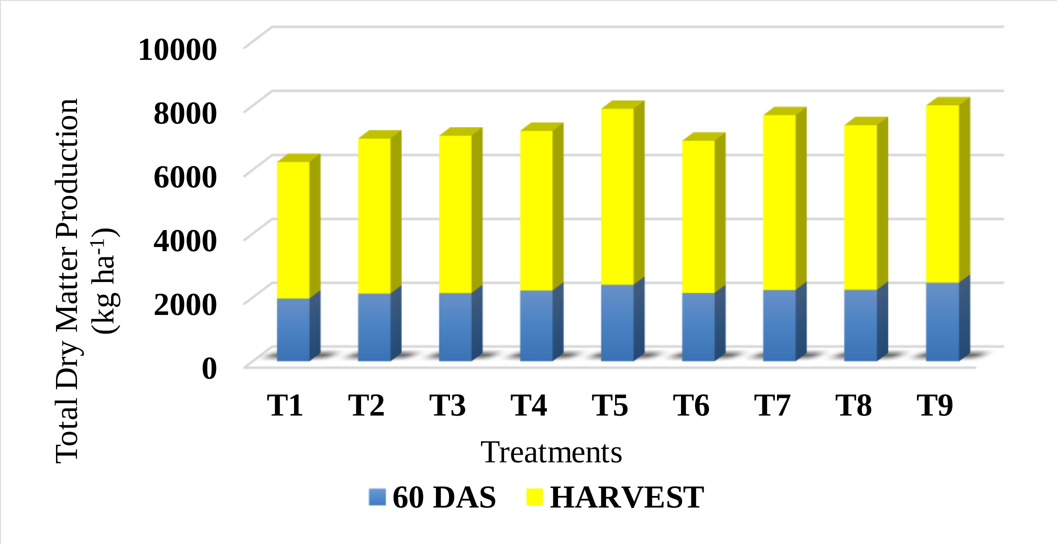


Fig. 6. Effect of cropping geometry and *in situ* soil moisture conservation practices on dry matter production (DMP) (60 DAS, harvest), kg ha^{-1}.

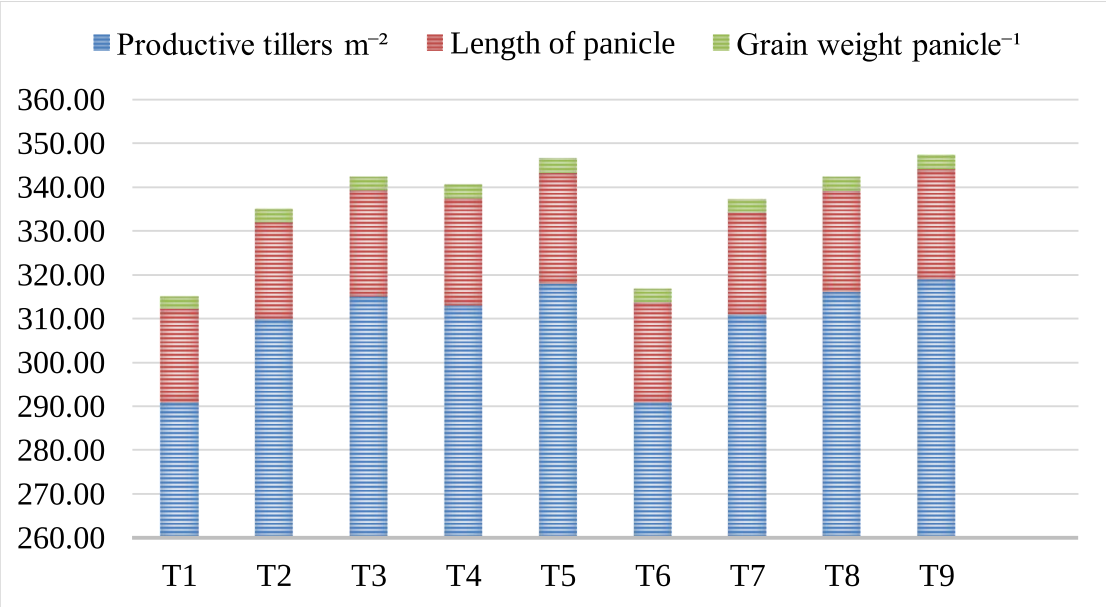


Fig. 7. Effect of cropping geometry and *in situ* soil moisture conservation practices on productive tillers m^{-2}, length of panicle and grain weight, grain weight $panicle^{-1}$.

Increased DMP due to hydrogel was attributable to higher carbohydrates, proteins, total amino acids and other biochemical and physiological parameters as reported by Kumar *et al.* (2018) in maize. This is in agreement with the findings of Yazdani *et al.* (2007) in soyabean. Coir pith compost application improved growth of plant through organic matter addition, improved soil physical properties, microbial properties and water holding capacity. Increased microbial activity led to faster decomposition and supplied nutrients to the growing plants and thereby increased the total DMP in treatment T_9. These findings were in conformity with the works of Kandiannan (1988) in sorghum and Lourduraj (2000) in groundnut, Kumar *et al.* (2018) in maize.

5.2 YIELD ATTRIBUTES AND YIELD

The results revealed favorable influence of paired row planting combined with live mulching of cowpea, hydrogel and coir pith compost application (Tables 6, 7 and Fig. 7, 8) on yield attributes, except panicle length and percentage of filled grains panicle^{-1}.

Paired row planting facilitates maximum light interception, better inter-culture operations and better soil aeration thereby creating a favourable condition for the better expression of yield attributes especially productive tillers m^{-2}, grain weight panicle^{-1}, number of spikelets panicle^{-1} and 1000 grain weight. This could be reason for obtaining the maximum yield in wider row spacing. This was in conformity with the findings of Bezbaruha *et al.* (2011). Live mulching with cowpea in treatment T_9 favourably influenced the number of productive tillers m^{-2}. Live mulching improved the soil physico-chemical and biological properties enhanced the soil organic matter status and water holding capacity improved the porosity and nutrient uptake and thereby improved the yield attributes as evident from Table 6 and 7. This was in conformity with the findings of, Aparna (2018) and Langangmeilu (2019) in upland rice. The ability of hydrogel to absorb moisture and gradually releasing it as per crop needs favourably influenced the yield attributes, economized water use and increased water use efficiency. This is in conformity with the findings of Kumar (2018) in maize. The unique property of coir pith compost to hold moisture more than 5 times of its weight and release it according to crop needs favourably influenced the yield attributes in rice. It also acts as an amendment which helps to build up biologically active root zone comprising the sub surface layers. Moreover, application of coir pith compost improved the soil physico-chemical and biological properties and thereby favourably influenced the yield attributes. Similar findings were reported by Parasuraman *et al.* (2003). The supremacy of paired row planting combined with live mulching of cowpea and application of hydrogel and coir pith compost in tapping and utilizing resources such as water, nutrients and light had a positive influence on yield attributes too.

Perusal of data revealed the profound effect of paired row planting combined with live mulching of cowpea and application of hydrogel and coir pith compost on grain and straw yields (Table 8 and Fig. 9). Though, the genetic composition of a crop cultivar is the main component determining its yield potential, the expression of morphological, physiological and biochemical factors finally decides the productivity of a crop in moisture stress situation. Yield is a complex attribute, which comprises the interaction of several intrinsic and exterior factors. It mostly depends upon the production and mobilization of carbohydrates, uptake of moisture and nutrients from soil in addition to a number of environmental factors to which crop is exposed during the growing period (Schonfeld *et al.*, 1988). Yield is the ultimate manifestation of a complex of factors. The favourable influence of paired row planting combined with live mulching of cowpea and application of hydrogel and coir pith compost (Treatment T_9) on growth attributes, DMP and yield attributes might have increased the grain and straw yields. Higher grain and straw yield in treatment T_9 would be attributed to higher photosynthetic efficiency, better translocation of photosynthates from leaf to grain resulting in higher dry matter production. An additional grain yield of 1,451 kg ha^{-1} was obtained in T_9 over T_1(Normal planting of upland rice). The percentage increase in yield of T_9 over T_1 was 61 percent. Better utilization of resources such as moisture, nutrients, light, improvement in soil physical, chemical and biological properties, better activity of soil microbial flora facilitating faster decomposition of organic matter might have increased the nutrient and organic status of the soil thereby favoring the crop

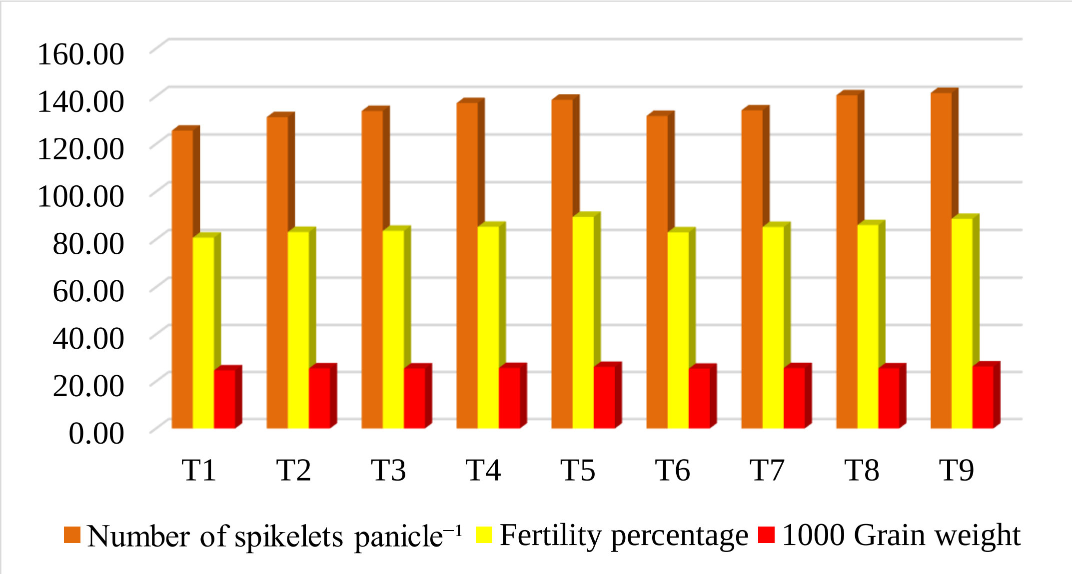


Fig. 8. Effect of cropping geometry and *in situ* soil moisture conservation practices on number of spikelets panicle^{-1}, percentage of filled grains panicle^{-1} and 1000 grain weight.

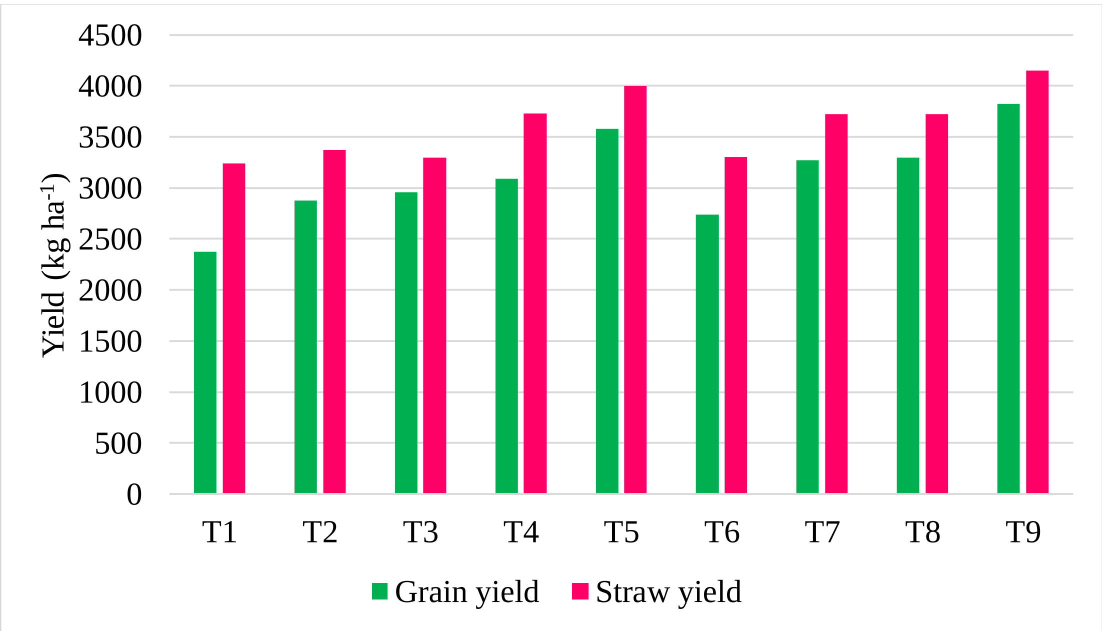


Fig. 9. Effect of cropping geometry and *in situ* soil moisture conservation practices on grain yield and straw yield, kg ha^{-1}.

to absorb more nutrients and this was reflected in higher grain and straw yield. Higher grain and straw yields due to T_9 over other treatments might be due to overall improvement in soil health, plant characters and DMP. Similar results were reported by Kumar (2018) in maize and Langangmeilu (2019) in upland rice.

5.3 PHYSIOLOGICAL AND CHEMICAL ESTIMATIONS

Perusal of the data revealed prominent influence of treatments on physiological parameters like RLWC and NPK uptake of crop at harvest.

The results in Table 9 revealed favorable influence of cropping geometry and *in situ* soil moisture conservation practices on RLWC of upland rice at flowering stage. Paired row planting combined with live mulching of cowpea, hydrogel and coir pith compost application showed the highest RLWC as live mulching, coir pith compost and hydrogel application improved the soil moisture retention capacity through enhanced physico-chemical and biological properties of soil. Hydrogel also extended the period of moisture availability and thereby longer period of moisture extraction by the plants from the soil and hence greater RLWC. This corroborates with the findings of Aparna (2018), Langangmeilu (2019) in upland rice and Ashraf *et al.* (2018) in cotton.

The results in Table 10 and Fig.10 revealed that the uptake of N, P and K were improved by the treatment T_9. Nutrient uptake is a product of nutrient content and dry matter accumulation. Nutrient uptake was boosted by paired row planting than normal row planting. Higher dry matter production under paired row spacing might be attributed to enhanced uptake of NPK. In general, when the uptake of N is higher, the crop would have propensity to absorb more P and K. Similar results of increased uptake of NPK due to varied cropping geometry was reported by Thavaprakaash and Velayudham (2007) in baby corn. Mulching improves the soil moisture availability and thereby plays a crucial role in uptake mechanisms of nutrients *viz.*, interception, mass flow and diffusion. This corroborates with the findings of Magalhaes *et al.* (1987) and Dutta (2006) in groundnut.

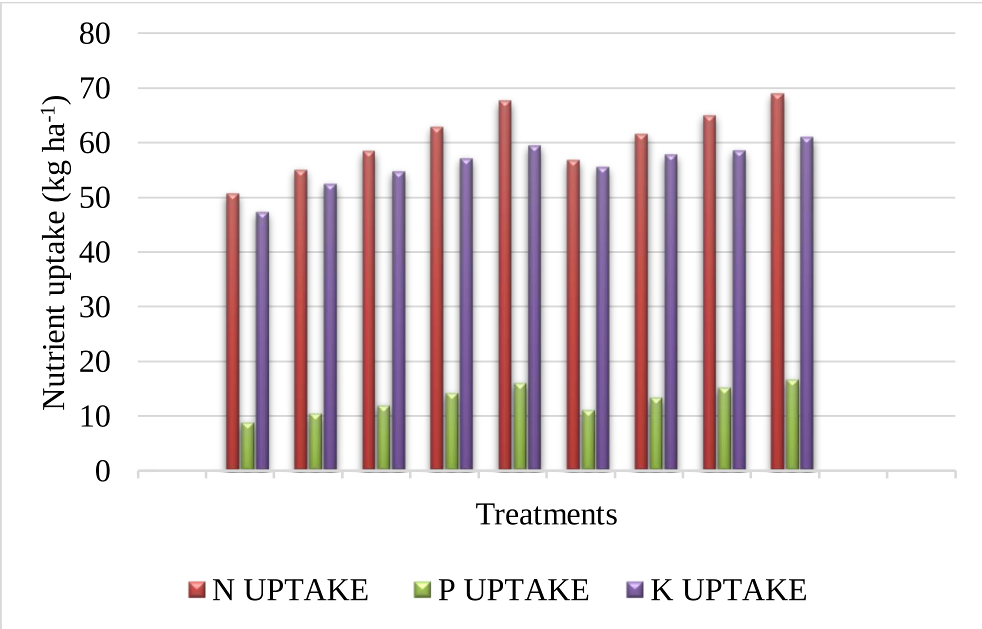


Fig. 10. Effect of cropping geometry and *in situ* soil moisture conservation practices on nutrient uptake by the crop at harvest, kg ha^{-1}.

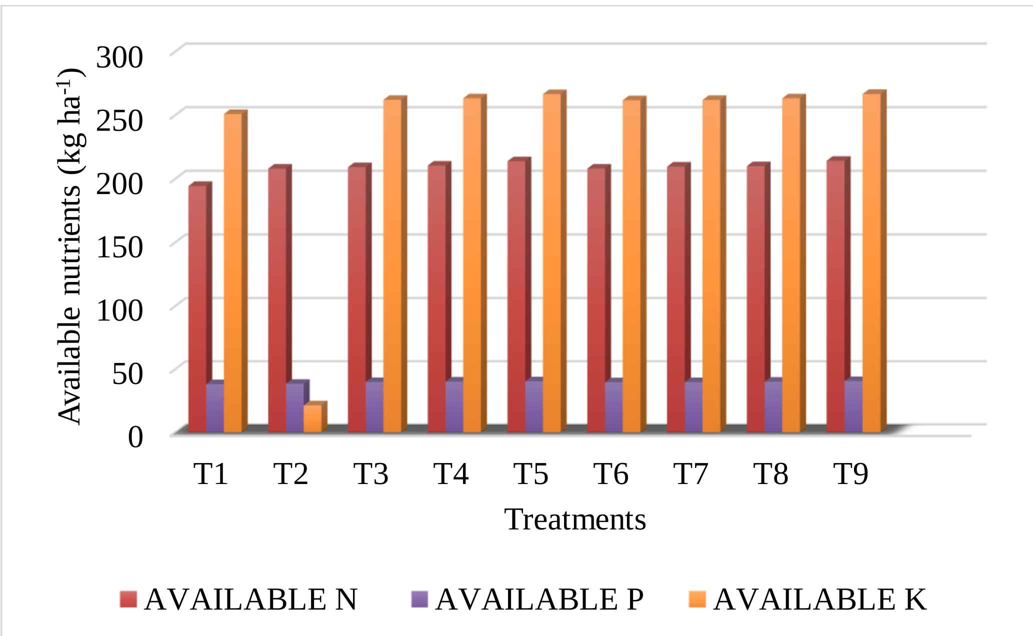


Fig. 11. Effect of cropping geometry and *in situ* soil moisture conservation practices on available N, P, K after harvest, kg ha^{-1}.

3.1 Treatment with cowpea

3.2 Treatment without cowpea

3.3 Cowpea harvest

3.4 Cowpea root nodules

3.5 Normal planting after cowpea harvest

3.6 Paired row planting after cowpea harvest

Plate 3. Treatments at different growth stages

The results in Table 11 and Fig. 11 revealed that the availability of nutrients (N, P and K) were significantly influenced by the treatments. The treatment T_9 resulted in the maximum availability of N, P and K in soil. This might be due to the application of mulching, which led to better moisture conservation and prodigious availability of nutrients in the soil. This confirms with the findings of Sharma *et al.* (2010) in maize-wheat cropping system. Application of mulching (green manure) increased the availability of nutrients, especially P, by increasing its mobilization and by the release of organic acids. This corroborates with the findings of Aparna (2018) and Langangmeilu (2019) in upland rice. The coir pith compost application lead to improved nutrient availability and uptake (Solaimalai, 2001).

5.4 ROOT PARAMETERS

The results in Table 12 and Fig. 12 revealed that the root parameters like root shoot ratio, root weight and root volume were not influenced by the treatments, whereas the root length was significantly improved by the treatments. The treatment T_9 recorded the maximum root length of 14.96 cm and this might be due to proper partitioning of biomass to different parts like leaf, stem, root and grains. This corroborates with the findings of Rathika (2008) in babycorn. Mulching acts as a buffer and protected the crop from temperature and moisture extremes, thus promoting the root growth. This substantiates with the findings of Ghosh *et al.* (2006) in groundnut. Polymers like hydrogel can store extra water more than 400 times of its weight and enables the plant to utilize water for an extended period of time which maintained proper growth and development of roots. This confirms with the findings of Meena *et al.* (2011) in tomato.

5.5 SOIL PARAMETERS

The results in Table 13 and 14 and Fig. 13 revealed that the soil parameters like bulk density, soil porosity and soil moisture content at 15cm depth at 45 DAS are not significantly influenced by the treatments. The soil moisture content at 15cm depth at 60 DAS and harvest was significantly influenced and the treatment T_9 resulted in the maximum soil moisture content. This is due to the application of hydrogel which improved the water holding capacity of soil, coir pith compost, which can absorb 400 times more moisture by its weight and mulching with cowpea, which covers and protects the soil from evaporation and thereby improves the moisture content.

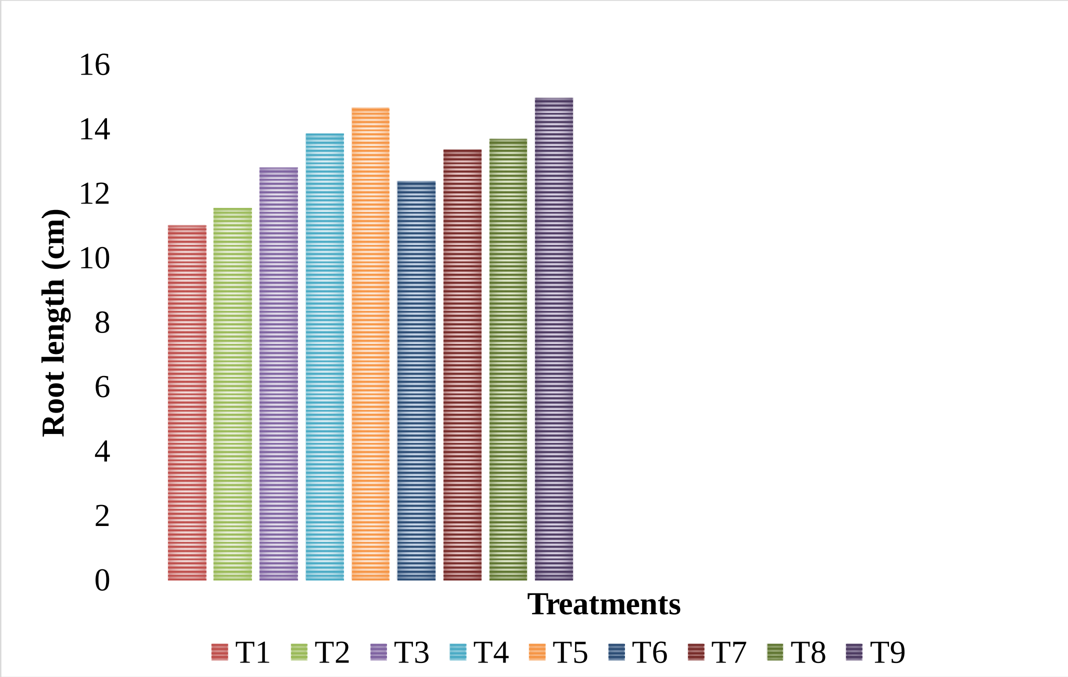


Fig. 12. Effect of cropping geometry and *in situ* soil moisture conservation practices on root length, cm.

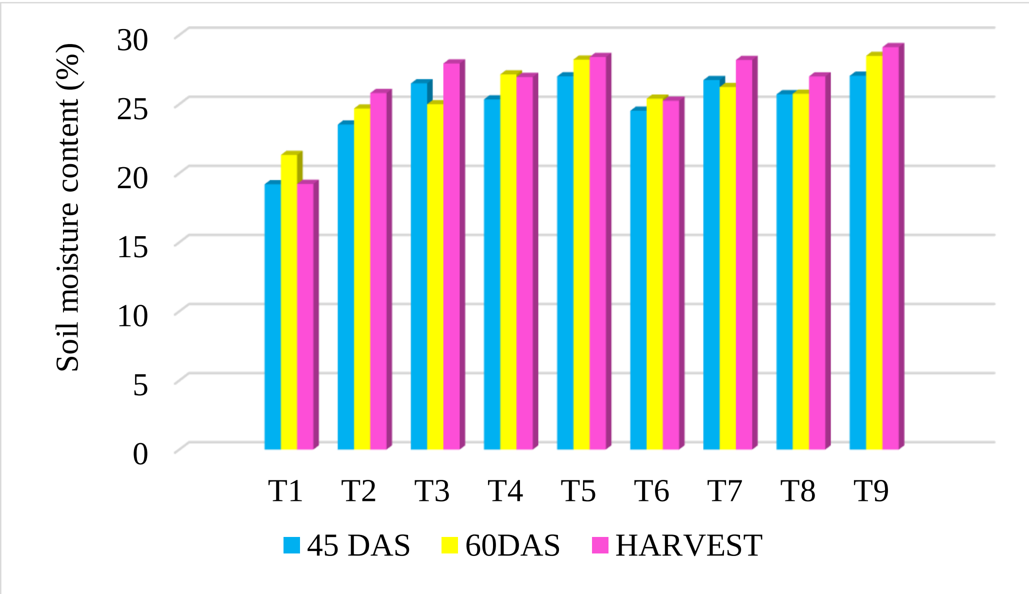


Fig. 13. Effect of cropping geometry and *in situ* soil moisture conservation practices on soil moisture content at 15cm depth.

This corroborates with the findings of Rehman *et al.* (2011) in aerobic rice, Kumar (2018) in maize, Aparna (2018) and Langangmeilu (2019) in upland rice.

5.6 MAJOR WEEDS OF UPLAND RICE

The results of Table 15 and Fig. 14 revealed that the weed dry weight was considerably influenced by the treatments at 45 DAS. The treatment T_7 resulted in the lowest weed dry weight and was on par with the other treatments, except T_1. Paired row planting with live mulching of cowpea and hydrogel application reduced the weed population and thereby its dry weight by the smothering effect of cowpea. Similar findings were reported by Aparna (2018) and Langangmeilu (2019) in upland rice.

5.7 ECONOMIC ANALYSIS

The results of the experimental study presented in the Table 16 and Fig. 15 revealed that the net income was significantly influenced by the treatments and the treatment T_9 resulted in the maximum net income of 62,887 ₹ ha^{-1} and was on par with the treatment T_7. The highest BC ratio of 1.84 was produced by the treatment T_7 and was on par with the treatment T_9. The BC ratio of the treatment T_9 is less compared to the treatment T_7. This is mainly due to the additional cost of coir pith compost included in the treatment T_9.

Paired row planting with live mulching of cowpea, hydrogel and coir pith compost application resulted in improved growth, yield attributes and yield and thereby recorded the highest net income. The highest net income was recorded by the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) and was in conformity with the findings of Mehta *et al.* (2012) in dill, Singh *et al.* (2018) in sugarcane, Kumar (2018) in maize, Aparna (2018) and Langangmeilu (2019) in upland rice.

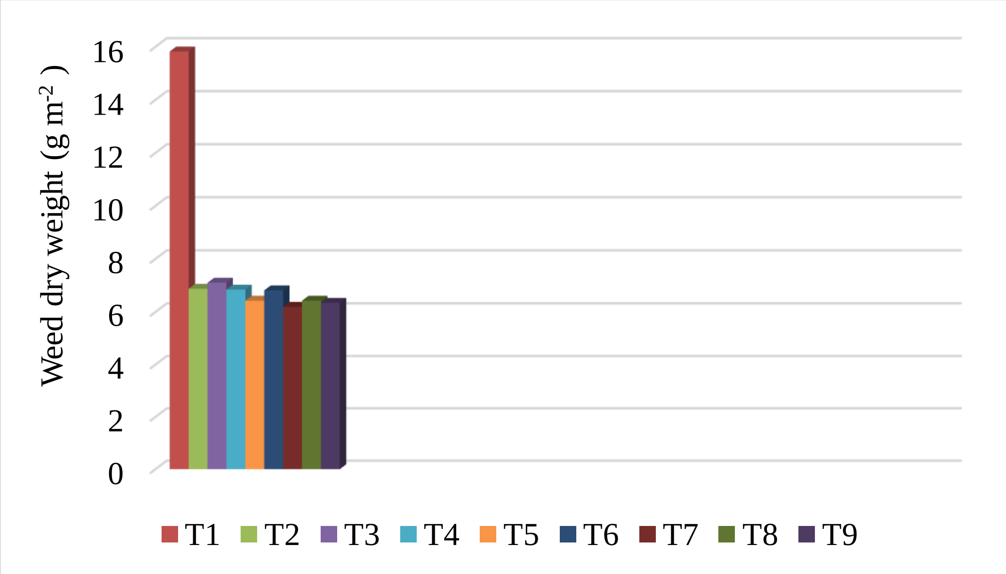


Fig. 14. Effect of cropping geometry and *in situ* soil moisture conservation practices on weed dry weight, g m^{-2}.

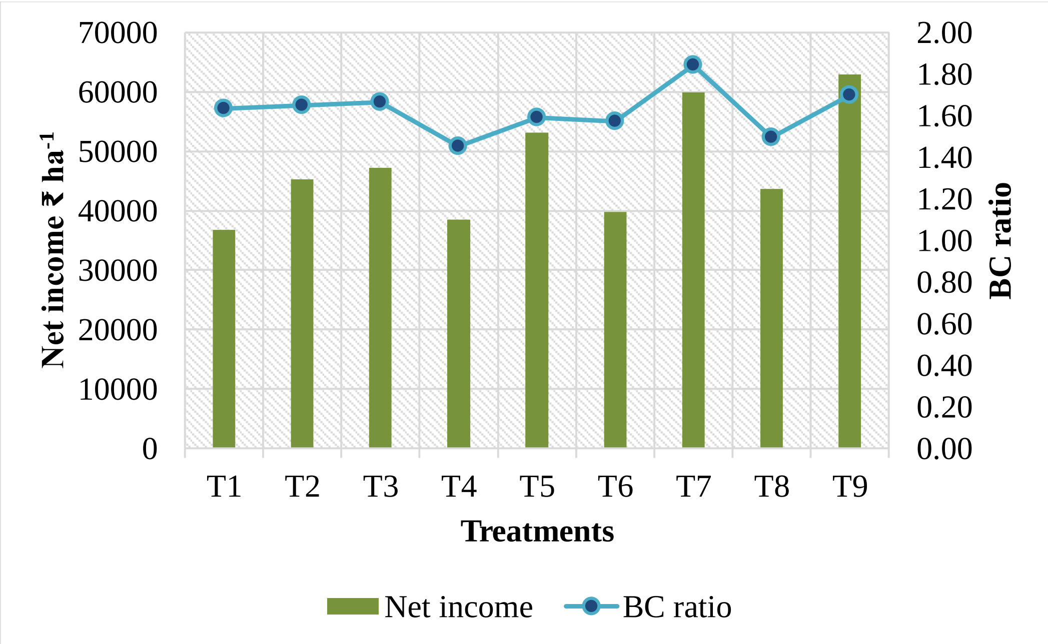


Fig. 15. Effect of cropping geometry and *in situ* soil moisture conservation practices on net income and BC ratio.

SUMMARY

SUMMARY

A field experiment entitled "Cropping geometry and *in situ* soil moisture conservation practices on upland rice (*Oryza sativa* L.)" was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram during Kharif, 2019. The experiment was laid out in randomized block design with 9 treatments and three replications. The treatments were T_1: Normal planting of upland rice (20 cm x 10 cm), T_2: Normal planting with live mulching of cowpea, T_3: Normal planting with live mulching of cowpea and hydrogel application, T_4: Normal planting with live mulching of cowpea and coir pith compost application, T_5: Normal planting with live mulching of cowpea and hydrogel + coir pith compost application, T_6: Paired row planting with live mulching of cowpea, T_7: Paired row planting with live mulching of cowpea and hydrogel application, T_8: Paired row planting with live mulching of cowpea and coir pith compost application, T_9: Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application. Uniform dose of 60 kg N, 30 kg P_2O_5, 30 kg K_2O ha^{-1} were applied to all the treatments along with 5 t FYM ha^{-1}. The variety used for the study was Aiswarya (PTB 52) for rice and MFC-0814 for cowpea. The soil was sandy clay loam in texture and low in available N, high in available P and medium in available K. The crop was sown on 14/06/2019 and harvested on 14/10/2019. The observations on growth characters, yield attributes, yield, physiological, chemical estimations, root, soil, weed parameters and economics were done and the data were analysed statistically and presented in this chapter.

The perusal of data revealed that the treatment T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application) produced taller plants at 60 DAS and the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) produced the tallest plants at harvest. The highest number of tillers were also produced by the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) at 60 DAS. Leaf area index was not profoundly influenced by the treatments though, the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) showed the highest value of LAI at 60 DAS. The maximum dry matter production was recorded by the treatment T_9 (Paired

row planting with live mulching of cowpea and hydrogel + coir pith compost application) both at 60 DAS and harvest.

The yield attributes *viz.,* productive tillers m^{-2}, grain weight $panicle^{-1}$, number of spikelets $panicle^{-1}$, 1000 grain weight, grain yield, straw yield and harvest index were significantly higher with the treatment T_9 and the treatment T_5 registered the highest length of panicle and percentage of filled grains $panicle^{-1}$. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) recorded the highest grain yield and straw yield of 3443 kg ha^{-1} and 3737 kg ha^{-1} respectively.

The perusal of data revealed favourable influence of treatments on the physiological parameter RLWC. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) resulted in the highest RLWC of 80.61 percent. But the physiological parameters *viz.,* proline and chlorophyll content were not significantly influenced by the treatments.

The nutrient uptake of N and K were highest for the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) and was on par with the treatment T_5. The highest P uptake was recorded in the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) and was superior to the rest of treatments. The availability of all nutrients (N, P and K) after the experiment were significantly influenced by the treatments and the treatment T_9 showed the highest availability of all the nutrients.

The root length was favourably influenced by the treatments and the treatment T_9 recorded the highest root length of 14.96, cm whereas other root parameters *viz.,* root shoot ratio, root weight and root volume were not significantly influenced by the treatments.

The soil parameters *viz.,* bulk density and porosity were not significantly influenced by the treatments. Even though not significant, the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) showed the highest value of porosity and low bulk density.

The important weeds observed in the experimental field were grasses (*Echinochloa colona, cynodon dactylon, Dactyloctenium aegyptium*), sedges (*Cyperus rotundus*) and broad leaved weeds (*Phyllanthus niruri, Alternanthera sessilis, Mimosa* *pudica*). The weed dry weight was considerably influenced by the treatments and the treatment T_1 (Normal planting of upland rice) showed the highest weed dry weight of 15.82 gm^{-2}. The lowest weed dry weight of 6.19 gm^{-2} was recorded in the treatment T_7 (Paired row planting with live mulching of cowpea and hydrogel application).

The major pest observed in the experimental field was rice gundhi bug. The important diseases observed were grain discoloration and blight. The incidence of pests and diseases never reached the threshold level and necessary control measures were taken.

The net income and BC ratio were profoundly influenced by the treatments. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) recorded the highest net income of 62,887 ₹ ha^{-1} was on par with the treatment T_7 and significantly superior to rest of the treatments. The lowest net income of 36,803 ₹ ha^{-1} was recorded by the treatment T_1 (Normal planting of upland rice). The treatment T_7 (Paired row planting with live mulching of cowpea and hydrogel application) showed the maximum BC ratio of 1.84 and was on par with the treatment T_9. The lowest BC ratio of 1.45 was recorded in the treatment T4 (Normal planting with live mulching of cowpea and coir pith compost application).

The results revealed higher growth characters, yield attributes, yield and net income of upland rice in the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application). Therefore, paired row planting with live mulching of cowpea along with combined application of hydrogel and coir pith compost could be recommended for upland rice.

Future line of work

The possibility of exploring naturally available, cheaper, biodegradable materials from tuber crops like sweet potato, yam, aroids and minor tuber crops have to be assessed in comparision with hydrogel and live mulching of cowpea, particularly in terms of soil moisture conservation, WUE, yield and economics of upland rice.

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7. REFERENCES

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APPENDIX

APPENDIX I

Weather parameters during the cropping period – 14th June to 14th October, 2019

Standard weeks	Temperature (°c)		Relative humidity (%)		Rainfall (mm)	Rainy days
	Max	Min	Max	Min		
24	31.13	24.83	93.37	81.17	114.40	6
25	31.91	24.93	90.00	78.71	28.60	3
26	32.09	26.06	87.14	75.29	0.00	0
27	32.20	25.91	90.29	77.14	32.10	2
28	30.79	25.37	90.29	79.00	42.10	2
29	30.06	23.74	94.14	81.57	100.80	4
30	30.37	24.33	92.29	82.43	7.70	2
31	31.46	25.63	89.29	77.57	17.50	1
32	30.00	23.61	94.57	81.71	198.10	6
33	30.44	24.07	91.57	76.57	18.20	2
34	31.11	24.23	92.14	77.43	34.90	3
35	30.67	23.91	93.14	77.86	91.90	6
36	30.87	24.37	90.57	80.14	84.00	3
37	31.33	24.39	88.86	76.43	12.90	2
38	30.94	24.90	91.14	77.86	19.40	2
39	31.01	24.21	93.29	75.57	123.80	4
40	31.50	24.57	91.29	72.14	7.00	1
41	31.10	24.40	91.71	77.00	133.10	4

CROPPING GEOMETRY AND *IN SITU* SOIL MOISTURE CONSERVATION PRACTICES IN UPLAND RICE

(*Oryza sativa* L.)

by

GUNTURI ALEKHYA

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ABSTRACT

Cropping geometry and *in situ* soil moisture conservation practices in upland rice (*Oryza sativa* L.)

A field experiment entitled "Cropping geometry and *in situ* soil moisture conservation practices in upland rice (*Oryza sativa* L.)" was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram during *Kharif*, 2019 with the objectives to study the influence of cropping geometry and *in situ* soil moisture conservation practices on growth and yield of upland rice and to work out the economics of cultivation. The variety used was Aiswarya (PTB 52). The experiment was laid out in randomized block design with 9 treatments and three replications. The treatments were T_1: Normal planting of upland rice (20 cm x 10 cm), T_2: Normal planting with live mulching of cowpea, T_3: Normal planting with live mulching of cowpea and hydrogel application, T_4: Normal planting with live mulching of cowpea and coir pith compost application, T_5: Normal planting with live mulching of cowpea and hydrogel + coir pith compost application, T_6: Paired row planting with live mulching of cowpea, T_7: Paired row planting with live mulching of cowpea and hydrogel application, T_8: Paired row planting with live mulching of cowpea and coir pith compost application, T_9: Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application..

The results revealed that the treatment T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application) produced taller plants at 60 DAS and the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) produced the tallest plants at harvest and highest number of tillers at 60 DAS. Leaf area index was not significantly influenced by the treatments, though the treatment T_9 showed the highest value of LAI at 60 DAS. The maximum dry matter production was recorded in the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) at 60 DAS and harvest.

The yield attributes *viz.*, productive tillers m^{-2}, grain weight $panicle^{-1}$, number of spikelets $panicle^{-1}$, 1000 grain weight, grain yield, straw yield and harvest index were significantly higher in the treatment T_9 (Paired row planting with live mulching of

cowpea and hydrogel + coir pith compost application) and the treatment T_5 (Normal planting with live mulching of cowpea and hydrogel + coir pith compost application) registered the highest length of panicle and percentage of filled grains panicle^{-1}. The treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) produced the highest grain yield of 3443 kg ha^{-1} and straw yield of 3737 kg ha^{-1}. The maximum harvest index of 0.48 was recorded in the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application).

The nutrient uptake of N, P and K were highest for the treatment T_9. The availability of all nutrients (N, P and K) after the experiment were significantly influenced and the treatment T_9 showed the highest availability of all the nutrients.

The root parameters *viz.*, root shoot ratio, root weight and root volume were not significantly influenced by the treatments, whereas root length was favourably influenced by the treatments and the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) produced the highest root length.

The economic analysis revealed that the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application) resulted in the highest net income. The treatment T_7 (Paired row planting with live mulching of cowpea and hydrogel application) showed the maximum BC ratio and was on par with the treatment T_9.

The results revealed that higher growth characters, yield attributes and yield of upland rice was recorded by the treatment T_9 (Paired row planting with live mulching of cowpea and hydrogel + coir pith compost application). Maximum net income was also recorded by the treatment T_9 and was on par with the treatment T_7. Therefore, paired row planting with live mulching of cowpea along with combined application of hydrogel and coir pith compost could be recommended for upland rice.

സംഗ്രഹം

കരനെല്ക്കൃഷിലെ "ഇടയകലവും മണ്ണിലെ ഈർപ്പസംരക്ഷണവും" എന്ന വിഷയത്തിൽ ഒരു പഠനം വെള്ളായണി കാർഷിക കോളേജിലെ ഇൻസ്ട്രക്ഷണൽ ഫാർമിൽ നടത്തുകയുണ്ടായി. കരനെല്ക്കൃഷിക്ക് അനുയോജ്യമായ ഇടയകലവും മണ്ണിലെ ഈർപ്പസംരക്ഷണവും കണ്ടുപിടിക്കുക എന്നതായിരുന്നു പഠനത്തിന്റെ ലക്ഷ്യം . പട്ടാമ്പി കാർഷിക ഗവേഷണ കേന്ദ്രത്തിൽ നിന്നും വികസിപ്പിച്ചെടുത്ത ഐശ്വര്യ എന്ന നെല്ലിനമാണ് പഠനത്തിന് ഉപയോഗിച്ചത്.

പരീക്ഷണത്തിൽ ഉപയോഗിച്ച വിവിധ അളവുകൾ താഴെ കൊടുത്തിരിക്കുന്നു.

T_1: സാധാരണ നടീൽ ഇടയകലം 20cm x 10cm

T_2: സാധാരണ നടീൽ + പയർ വിള തത്സമയ പുതയിടൽ

T_3: സാധാരണ നടീൽ + പയർ വിള തത്സമയ പുതയിടൽ + ഹൈഡ്രോജൽ

T_4: സാധാരണ നടീൽ + പയർ വിള തത്സമയ പുതയിടൽ + ചകിരിച്ചോർ

T_5: സാധാരണ നടീൽ + പയർ വിള തത്സമയ പുതയിടൽ + ഹൈഡ്രോജൽ + ചകിരിച്ചോർ

T_6: ജോഡിയാക്കിയ വരി നടീൽ + പയർ വിള തത്സമയ പുതയിടൽ

T_7: ജോഡിയാക്കിയ വരി നടീൽ +പയർ വിള തത്സമയ പുതയിടൽ + ഹൈഡ്രോജൽ

T8: ജോഡിയാക്കിയ വരി നടീൽ + പയർ വിള തത്സമയ പുതയിടൽ + ചകിരിച്ചോർ

T9: ജോഡിയാക്കിയ വരി നടീൽ + പയർ വിള തത്സമയ പുതയിടൽ + ഹൈഡ്രോജൽ + ചകിരിച്ചോർ

മൊത്തം 9 ട്രീറ്റ്മെന്റ്കളായി മൂന്നു തവണ ആവർത്തിച്ചു റാൻഡമൈസെഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന രീതിയിലാണ് പഠനം നടത്തിയത്. 60 കിലോ നൈട്രജൻ, 30 കിലോ ഫോസ്ഫറസ്, 30 കിലോ പൊട്ടാസ്യം, 5 ടൺ കാലിവളം എല്ലാ ട്രീട്മെന്റിലും നൽകി.

ഈ പഠനത്തിന്റെ പ്രധാന കണ്ടെത്തലുകൾ ഇവയാണ്. ജോഡിയാക്കിയ വരി നടീൽ + പയർ വിള തത്സമയ പുതയിടൽ + ഹൈഡ്രോജൽ + ചകിരിച്ചോർ (T9) എന്നിവ കരനെല്ക്കൃഷിയിൽ കൂടുതൽ വിളവിനും വൈക്കോൽ ഉത്പാദനത്തിനും മണ്ണിലെ ഈർപ്പസംരക്ഷണത്തിനും നല്ലതാണെന്ന് കണ്ടെത്തി. കൂടാതെ കർഷകന്റെ അറ്റാദായവും വർധിക്കുന്നതായി തെളിഞ്ഞു.