Original Research Article

EFFECT OF MICROCLIMATE MODIFICATION ON GROWTH AND YIELD OF PEARL MILLET UNDER DIFFERENT LAND CONFIGURATION, MULCHING AND WATER STRESS

ABSTRACT

The field experiment was conducted in the summer season from February to May, 2022 at Eastern Block Farm, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore. To study the effect on microclimate modification, pearl millet variety (CO 10) was sown under three levels of land configurations with two levels of mulching and two levels of water stress conditions. The experiment was accomplished of 12 treatment combinations and laid out in Factorized Random Block Design replicated thrice. The results of the experiments revealed that the paired row with intercropping approach produced the best growth parameters, such as plant height, leaf area index, dry matter accumulation and yield followed by paired row sowing and normal sowing. In terms of water stress, the same trends were observed maximum when applied irrigation at 0.75 IW/CPE ratio as compared to 0.5 IW/CPE moisture regimes. In relation with mulch and without mulch treatments, the mulched treatments for both levels of irrigation and at different land configurations were higher. Therefore, irrigation at 0.75 IW/CPE, paired row along with intercropping and mulch application could be applied for higher growth attributes and yields of pearl millet for appreciable saving of water in summer season.

Keywords: Land configuration, Microclimate, Moisture regime, Mulching, Yield

1. INTRODUCTION

The unpredictability and variations in the climate have the most impact on agriculture. It has become increasingly vulnerable to climatic threats as a result of significant variability in recent years, as well as an increase in the frequency and intensity of extreme weather incidents [9]. Effective adaptation strategies must be implemented since a rise in temperature will likely to reduce crop production. Thus, by making some crop management amendments like modifying the crop microclimate without facing considerable financial expenditures, making it more favourable for yield enhancement and production [10]. To alleviate the adverse impacts of climate change, this study suggests appropriate land configurations, optimal irrigation requirements and mulching to conserve soil moisture under water stress during the summer season.

Pearl millet is primarily used as a staple food grain, feed and fodder. It is suitable and efficient for semiarid climates due to its efficient use of soil moisture and higher level of heat tolerance than sorghum and maize. It has a prominent position in dryland agriculture, contributing considerably to the country's food security because to its intrinsic drought resistant mechanism and adaptation to drier and low fertile conditions. To enhance and improve agricultural production, we should examine for better treatments to utilise the available resources and land. This aim can be accomplished by intercropping, which is a beneficial method for enhancing overall production per unit area of land per unit time by growing more than one crop in the same field while modifying crop geometry. The microclimate can also be modified by intercropping practices to minimize intensity of light, air temperature, desiccating wind, and other environmental factors. Pearl millet growth, yield and nutrient uptake were significantly higher in modified planting patterns, such as ridge and furrow, paired row and paired rows + intercrop, than in the uniform row system.

Water shortage is creating a barrier to food production, particularly in arid and semi-arid countries. As a result, water-saving methods that have the potential to increase water production in water-stressed areas must be implemented. Irrigation scheduling based on pan evaporation data is expected to increase agricultural yield by at least 15-20 %. The availability of soil moisture until the crop reaches maturity is critical to realising its yield potential. Mulching is an efficient method of controlling the crop-growing environment have positive benefits on soil-water conservation, reduces evapo-transpiration by decreasing evaporation, maintenance of canopy temperature at the grain-filling stage which save the crop from the terminal heat effects [16].

2. MATERIALS AND METHODS

The present study was conducted as field experiment during summer season at Eastern Block Farm, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore. The experiment was laid out in Factorized Random Block Design (FRBD). There were 12 treatments comprised of two levels of mulching [M_1: with mulching and M_2: without mulching], two levels of moisture regimes [I_1: 0.75 IW/CPE ratio and I_2: 0.5 IW/CPE ratio] and three levels of land configurations [L_1: Normal row sowing, L_2: Paired row sowing and L_3: Paired row sowing with green gram intercropping] with three replications. The daily pan evaporation data were computed using an open pan evaporimeter situated at the meteorological observatory. The quantity of irrigation water applied in surface flooding was measured by 7.5 cm head Parshall flume. A fixed depth of 50 mm irrigation water was applied to each treatment based on IW/CPE ratio of 0.5 and 0.75. Crop was fertilized with blanket recommendation 75:30:30 N, P_2O_5, K_2O kg ha^{-1}. Top dressing of nitrogen at 15 and 30 Days After Sowing (DAS). The statistical analysis of data was done using analysis of variance (ANOVA) technique for Factorized Random Block Design at 0.05 probability level.

2.1. Influence of microclimatic characters

A digital soil thermometer (Model KUSAM MECO-936) with a probe inserted at 15 cm depth of soil to record soil temperature (°C). At weekly intervals, soil temperature was monitored at 0600 hrs, 1000 hrs, 1400 hrs, and 1800 hrs. A digital soil moisture instrument (Model HH2 Delta Theta probe ML2x) was used to measure the soil moisture. To monitor soil moisture, the sensor was inserted inside the soil and can be expressed in percentage.

The canopy temperature (°C) was measured using an infrared thermometer (Foopro, Raytek, USA). The angle of the infrared thermometer for the measurement was set to 45° horizontally and the results were recorded. Photosynthetically Active Radiation (PAR) was detected using an EMCON Line quantum sensor at 30, 45, 60, 75 DAS and at harvest. Along the planting rows, the line quantum sensor was installed. Between the hours of 1130 and 1200, observations were made. The following formula was used to determine light interception and expressed in percentage.

$$\text{PAR interception (\%)} = \frac{\text{PAR (I)} - \text{PAR (T)} - \text{PAR (R)}}{\text{PAR (I)}} \times 100$$

Where, PAR (I) = Total PAR incoming above the canopy (W m^{-2}),

PAR (T)= PAR transmitted to ground (W m^{-2})

PAR (R)= PAR reflected from the canopy (W m^{-2})

2.2. Influence of growth and yield parameters

Before the panicle initiation stage, the plant height was measured from the ground level to the tip of the longest leaf and once after the panicle initiated, it was measured from the ground level to the top of the panicle. The average height was determined and given in centimetres. Five plants were carefully plucked from sampling rows. After that, the samples were washed, shade dried, and oven dried at 70±5 °C until a consistent weight was achieved and the dry weight was recorded. The data were recorded for grain and stover yield on net plot basis and then converted on hectare basis.

3. RESULTS AND DISCUSSION

Plant development, yield qualities, and physiological and micrometeorological features were all periodically observed. The information was statistically examined and presented here with an interpretation under the relevant topics.

Table 1: Mean values of PAR interception (%), Canopy temperature (°C), Soil temperature (°C) and Soil moisture (%) of pearl millet under different land configuration, water stress and mulch application during summer season.

Treatments	PAR interception (%)	Canopy temperature (°C)	Soil temperature (°C)	Soil moisture (%)
Land configuration				
L_1 - Normal sowing	58.8	31.1	32.4	24.3
L_2 - Paired row sowing	62.4	31.3	32.9	24.0
L_3 - Paired row sowing with Green gram intercropping	66.3	30.8	31.7	25.8
Mulch application				
M_1 - With mulching	63.5	30.7	32.2	26.8
M_2 - Without mulching	61.6	31.4	32.8	21.3
Water stress				
I_1 - 0.75 IW/CPE	63.4	30.9	32.1	25.9
I_2 - 0.5 IW/CPE	61.7	31.1	32.5	22.8

3.1. Photosynthetically Active Radiation (PAR)

On an average PAR interception was higher (66.3%) in paired row sowing with intercropping and on par at paired row sowing (62.4%) as compared to normal sowing (58.8%) as shown in Table 1. Even though sole cropping had a high PAR interception rate, the pearl millet in an intercropping system pattern would have converted the PAR more effectively to biomass [17]. Intercropping with green gram (S1) shows significantly higher LI (88 %) at 60 DAS [15]. In comparison with moisture regimes, 0.75 IW/CPE resulted the light interception of 63.4% while 0.5 IW/CPE have resulted as 61.7%. The direct impact of water stress diminished the canopy light interception [6]. Crop development was impacted by water stress, which decreased intercepted PAR. Mean value of PAR interception was higher in mulched plots (63.5%) compared to without mulched plots (61.6%) during the study. In rice straw residue plots, PAR interception was observed as higher in wheat crop [4].

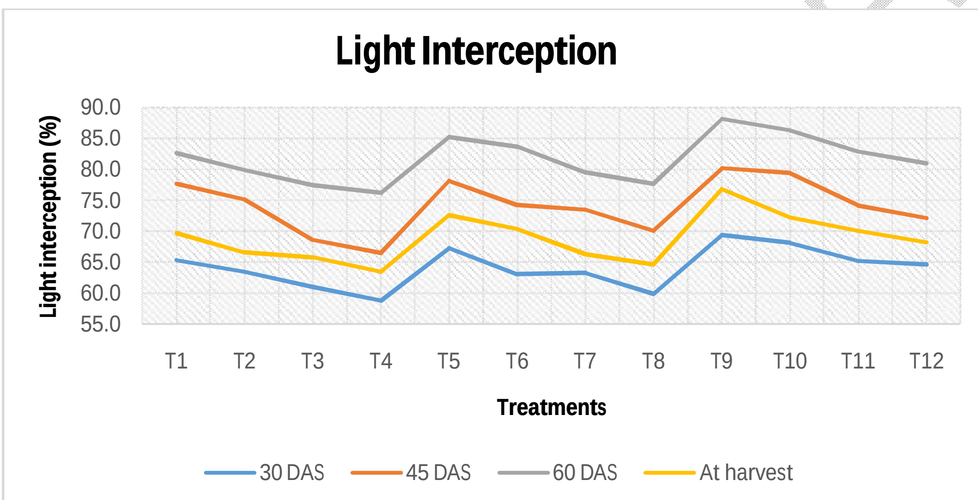

Fig 1. *Mean PAR light interception of the crop growing period*

From *Fig 1*, higher interceptions were observed in paired row systems (T_5 to T_{12}) compared to normal sowing (T_1 to T_4). Crops featuring narrow spacing covers the soil more effectively than crops with other crop geometry, which improved light interception.

3.2. Canopy temperature

The data revealed that paired row sowing showed an increase in canopy temperature of 31.3°C at par with normal sowing (31.1°C) and lower in paired row with intercropping (30.8°C). In comparison with 0.75 IW/CPE (30.9°C), the canopy temperature was higher (31.1°C) under 0.5 IW/CPE as furnished in Table 1. Due to appropriate moisture availability under 100 mm CPE irrigation regime, the canopy temperature was much lower while inadequate moisture condition under 150 mm CPE irrigation regime, the canopy temperature was higher [20]. Canopy temperature was higher (31.4°C) in non-mulched plots as compared to mulched plots (30.7°C) during the study period (Table 1). In the mulched crop, the canopy temperature was 0.5-1.0°C lower than in the unmulched crop. Larger leaf area index found under mulching, resulting in more transpiration, resulting in lower canopy temperature as compared to plots without mulching. Under black plastic mulch, a decrease in tomato canopy temperature [18].

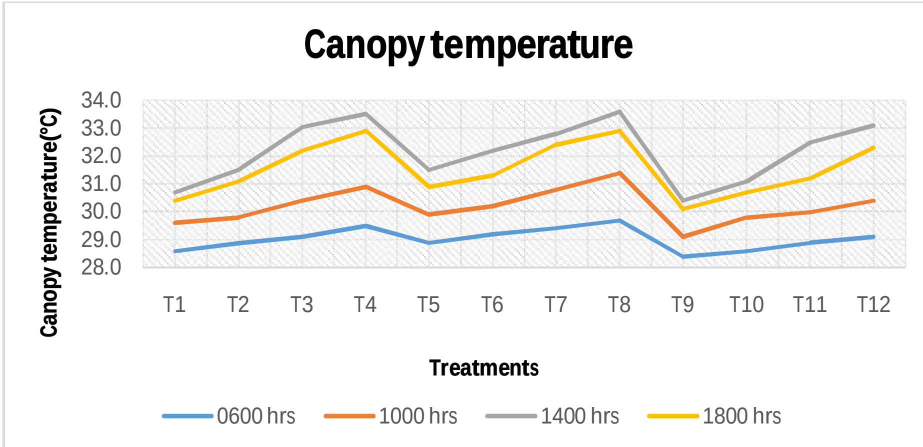

Fig 2. Mean canopy temperature of the crop growing period

From *Fig 2*, canopy temperature was maintained in mulched plots (T_1, T_2, T_5, T_6, T_9, T_{10}) during the crop growing period. As a result of stomatal closure under water stress conditions, canopy temperature rises in without mulching (T_3, T_4, T_7, T_8, T_{11}, T_{12}) compared to mulched treatments.

3.3. Soil temperature

The influence of agricultural residue on crop development is monitored using soil temperature. In summer season, soil temperature can be reduced by mulch application. The accumulation of mulch aids in regulation of soil temperature balance by elevating in the morning and diminishing in the afternoon [2]. Among the different land configuration, mean soil temperature was higher under paired row sowing (32.9°C) and par with Normal sowing (32.4°C) as compared to paired row with green gram intercropping which resulted 31.7°C as represented in Table 1. Mean soil temperature was higher in 0.5 IW/CPE as compared with 0.75 IW/CPE. Better soil moisture management following imposed irrigation was the main factor in the regulation of the temperature environment. The data on the influence of mean soil temperature revealed that it was higher in unmulched plots (32.8°C) compared with mulched plots (32.2°C).

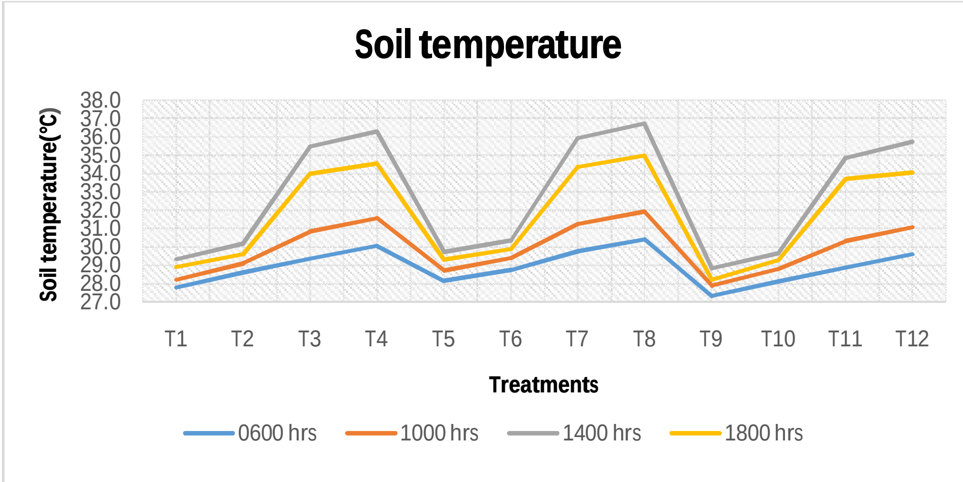

Fig 3. Mean soil temperature of the crop growing period

From *Fig 3*, paired row with intercropping (T_9 to T_{12}) have been resulting less soil temperature compared to other land configurations. Due to their deep roots and effective heat tolerance, legumes were able to partially withstand the impacts of high soil temperature. Mulching reduces evaporation from the top soil and helps in water retention thus maintaining lower soil temperature (T_1, T_2, T_5, T_6, T_9, T_{10}) compared to without mulch treatments.

3.4. Soil moisture

The data on the influence of soil moisture at weekly intervals and before harvest revealed that paired row spacing technique with green gram intercropping, conserved 25.8 % more soil moisture on par to paired row sowing at 24.0% over normal sowing values 24.3 % as referred in Table 1. Higher grain and dry matter production with 0.75 IW/CPE (25.9 %) compared to 0.5 IW/CPE (22.8%) could be due to enhanced soil moisture and quicker nutrient uptake, allowing the plant to reach its full potential [18]. The mean soil moisture in mulched plots was 26.8 %, while it was 21.3 % in non-mulched plots. Soil moisture was found to be greater in mulched plots than in non-mulched [5].

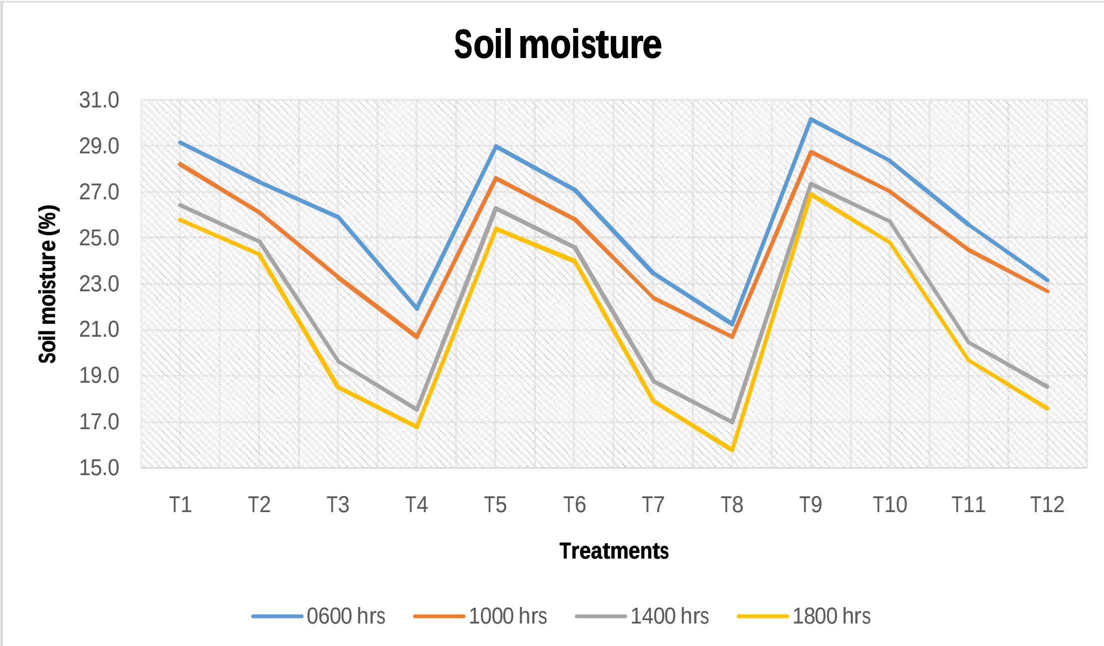

Fig 4. Mean soil moisture of the crop growing period

From Fig 4, sole crops pearl millet had lower moisture content than pearl millet with intercrop (T_9 to T_{12}). The increased soil moisture content observed intercropping was due to the higher canopy's shading effect, which reduced soil evaporation losses. Since legumes have deep root systems, they significantly reduce soil water extraction from the topsoil. Mulching helps to conserve soil water by decreasing soil evaporation and maintaining soil temperature, which minimizes the necessity for irrigation during crop growing season.

Table 2: Yield and yield attributing characters of pearl millet at harvest under different land configuration, water stress and mulch application during summer season.

Treatments	No of productive tillers plant^{-1}	Plant height (cm)	Length of ear head (cm)	Dry Matter Production (kg ha^{-1})	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Land configurations						
L_1 - Normal sowing	5.8	181.2	24.8	5567	2729	4076
L_2 - Paired row sowing	5.9	190.6	23.9	5845	2890	4427
L_3 - Paired row sowing with Green gram intercropping	6.0	193.8	25.1	6430	2954	4564
CD (0.05)	0.1663	8.706	NS	22.73	252	154
Mulch application						
M_1 - With mulching	6.0	194.4	24.9	6333	3153	4484
M_2 - Without mulching	5.8	182.7	24.3	5561	2556	4228

CD (0.05)	0.0999	7.109	NS	18.56	205	125
Water stress						
I_1 - 0.75 IW/CPE	6.1	190.9	24.7	6056	3215	4508
I_2 - 0.5 IW/CPE	5.7	186.2	24.5	5839	2493	4204
CD (0.05)	0.0999	NS	NS	18.56	205	125
Interaction						
SEd	0.08343(LM)	8.396	1.104(LMI)	15.50(LM)	140.04(MI)	104.67(LM,LI)
CD (0.05)	0.1730	NS	2.290	32.157	290.42	217.07

3.5. Plant height

Crop sown on paired row with green gram intercropping produced maximum plant height (132.5 cm) at all the growth stages, which was significantly superior over paired row sowing (127.7 cm) and normal sowing (125.8 cm) as presented in Table 2. Increased soil aeration, nutrient and moisture availability to the plant observed under alternative land configurations [7].

When irrigation was done at 0.75 IW/CPE ratio rather than 0.5 IW/CPE moisture regime, the highest plant height was seen. The minimal plant height and leaf area index were attained at all stages under 0.5 IW/CPE ratio due to poor root growth caused by moisture deficit [14]. The increased plant height in mulched plots can be attributed to greater resource usage due to a weed-free environment, which increases shoot growth. Mulched plots measured 129.8 cm in height, while unmulched treatments measured 126.3 cm. This can be ascribed to higher light interception and plant height in residue-sown crops, as well as the crop's favourable growth environment [4].

3.6. Dry Matter Production

Differential land configurations have significant influence in dry matter production (Table 2). The highest value was recorded on paired row with green gram intercropping (3920 kg ha^{-1}) followed by paired row sowing and normal sowing which shown 3568 kg ha^{-1} and 3404 kg ha^{-1} respectively. The enhanced DMP could be attributed to component crops capacity to maximise resource consumption due to a distinct rooting pattern for resource usage, resulting in less competition [1].

Under moisture regimes, significantly affected on dry matter accumulation (Table 2). The maximum dry matter accumulation was recorded with irrigation at 0.75 IW/CPE ratios (3640 kg ha^{-1}). The lowest dry matter accumulation was obtained under 0.5 IW/CPE ratios (3521 kg ha^{-1}). Least amount of irrigation application, resulting in lower plant height, leaf area, and nutrient uptake, which in turn reduced photosynthetic activity, resulting in lower dry matter production [11].

Crops with residue recorded significantly more crop dry matter as compared to without residue (Table 2). Plots treated with rice straw residue revealed 3864 kg ha^{-1} while without mulched plots, the observed value was 3397 kg ha^{-1}. Increased grain yield in rice straw mulch plots was related to the accumulation of higher vegetative biomass at anthesis due to a longer vegetative phase and a longer grain filling period. The dry matter accumulation (g/plant) of pearl millet was much higher as a result of the mulch and organic sources [13].

3.7. Yield and yield attributes

Among different land configurations, the yield and yield attributes (No. of. productive tillers per plant, ear head length, grain yield and stover yield) were higher in paired row with intercropping followed by paired row and normal sowing. In paired row with intercropping, ear head length was greater than in normal sowing and paired row sowing. In relation to two levels of irrigation regimes, 0.75 IW/CPE show superior results compared to 0.5 IW/CPE irrigation regime. Mulched plots have resulted higher yield and yield attributes in comparison with no mulching treatment. The values were presented in Table 2.

The enhanced photosynthesis in the paired row planting technique was caused by the higher yield attributes, which may be the result of improved nutrient and utilization of solar energy [3]. Crops with appropriate moisture availability at a 0.75 IW/CPE ratio experienced higher growth parameters and yield characteristics. Poor moisture supplies during the 0.5 IW/CPE ratio decreased the yield attributes and led to a poor yield of grain and stover [12]. Mulched plots produced greater yields and improved crop development, which they attribute to soil moisture conservation and temperature reduction [8].

4. CONCLUSION

The study acknowledged the fact that warming scenarios could adversely influence the growth and performance of pearl millet in both semi-arid and arid agro climatic conditions. However, microclimatic alterations through changes in land configuration, irrigation and mulch application can show effective adaptive strategies to mitigate adverse weather susceptibility and climatic risks in field crops. Intercropping legumes decrease soil temperature, accelerate foliage and canopy cover of the soil which ensure the favourable growth and yield of pearl millet. This enhance radiation interception and subsequent conversion into biomass. Mulches prevent the water loss from soil evaporation which is very helpful during the summer season. These findings have implications with respect to microclimate modification were paired rows of pearl millet with intercropping by scheduling 0.75 IW/CPE irrigation regime with mulching, creates a favourable environment for the development and yield qualities of summer pearl millet under water stress.

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