**Chapter 1**

**Site characteristics**

The study was conducted at the Texas Tech Quaker Avenue Research Farm, Lubbock, Texas (33° 41’ 36.4596” N, -101° 54’ 18.612 “W, 992 m a.s.l.). The study site has a semi-arid climate with a long-term average annual rainfall of 472 mm and an average annual temperature of 16 0C. July is the hottest month with an average monthly temperature of 27.2 0C, and January is the coldest month with an average monthly temperature of 4.4 0C. During the growing season of 2021 (May – September), the field received an average rainfall of 336.5 mm. (add seasonal data from ATMOS, Soil classification with texture, % clay, silt and sand, bulk density). The mean soil pH is 8.49 + 0.17 and the soil has 1.042 + 0.10 % organic matter at 0-10 cm depth. Also, the total amount of rainfall recorded since planting was 13.25 inches.

**Experimental Design**

The field experiment had paired, nested design with irrigation applied at the plot level and warming and residue applied at the subplot level. The field was divided into three blocks, and each block had a paired plot. One plot from each paired plot received irrigation treatment, and another plot in the pair was assigned dryland. A total of 8.60 inches of irrigation water was added for the growing season and there was a buffer zone of 4 m between the irrigated plots and dryland plots. Each plot consisted of eight 1m \* 1m subplots. The subplots were 1 m apart from one another. The warming and residue treatments combinations were randomly administered at the subplot level within the plot. Thus, four treatment combinations, i.e., control (C), warming (W), residue (R), and warming plus residue (WR), were applied uniformly in both dryland and irrigated plots. Warming plots were passively warmed throughout the growing season using 1m× 1m× 1m sized open-top chambers (OTC) made of aluminum rod and transparent polycarbonate sheets. We installed OTC in the field immediately after sowing cotton seeds by fixing them on the ground using stakes and zip ties. Multispecies grass residue was applied at 3 kg/m2 in the subplots with residue treatments. Each treatment combination was replicated six times, i.e., every plot comprised of two subplots of each treatment combination. Therefore, we had a total of 48 subplots (two warming levels × two irrigation levels × two residue levels × six replicates).

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Description automatically generated

Figure 1: Diagrammatic representation of the experimental design. Plots are 1m × 1m. Four different colors represent four individual treatments.

**Soil sampling and measurements:**

In late October, soil samples were collected from each subplot immediately after crop harvesting. We used a soil core (3 cm diameter) to collect samples from 0-15 cm depth. Each subplot is divided into two halves, and one sample is collected from each half. The soil was collected from three different locations and mixed to get one composite sample. Therefore, a total of 96 soil samples were collected from the field. The soil samples were packed in a refrigerated container and transported to the laboratory. The samples were then passed through a 2-mm sieve to remove larger plant roots, residue and stones and stored at 5 0C. The processed soil samples were sent to Waters Agricultural Laboratories Inc. for chemical analysis, where they were analyzed for soil organic matter, pH, CEC, and macro and micronutrients availability.

Soil temperature and volumetric moisture content were recorded from each subplot at 10 cm soil depth using 5TM sensors (Meter Group, Inc. Pullman, WA, USA) connected to the EM50 (Meter Group, Inc., Pullman, Washington, USA) data loggers. EM50 loggers were programmed to record soil temperature and moisture at every 30-minute interval. The gravimetric moisture content was determined by oven drying at 60 0C for 48 hours. Our field was also instrumented with ibuttons (Maxim Integrated, California, USA), a battery-sized logger recording air temperature and humidity. Ibuttons were fixed 75cm above the ground surface and programmed to record air temperature and humidity every 4 hours from the plant canopy. The light intensity was measured using HOBO Pendant Temperature/light data loggers (Onset Computer Corp., Massachusetts, USA), which measured the amount of light intercepted near the leaf canopy. The weather data were recorded using a weather station installed at the center of the research field.

The chloroform fumigation extraction technique was used to measure microbial biomass carbon (MBC) (citation). Two 5g equivalent of soil samples were weighted in the opaque container and one sample is fumigated with 25 ml of chloroform for 48 hours while another was left unfumigated. Both samples were then extracted using 0.5 M K2So4. The total carbon in the extracts was measure using the spectrophotometer. The procedure is repeated twice and average of two replicates was taken as final MBC. Similarly, we measured soil respiration using a Li-8100A soil CO2 flux system (Li-Cor Inc, Nebraska, USA). A soil collar of 20 cm diameter was installed 2-3 deep into the soil in each subplot at the starting of the experiment. We took soil respiration measurement from soil collar three times throughout the growing season. The plant structures inside the soil collar were periodically removed to eliminate the respiration of plant tissue.

Results:

Table 1:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | P | K | Ca | Mg | S | Fe | Zn | B | Mn | Cu | Na | pH | CEC |
| C | 29.08±8.00 | 993.68±136.61 | 3504.64±496.27 | 1790.88±247.01 | 26.0±4.72 | 73.60±10.15 | 1.77±0.23 | 9.75±1.14 | 166.72±11.13 | 3.16±0.36 | 211.00±59.26 | 8.63±0.17 | 19.34±2.12 |
| R | 29.26±6.88 | 993.88±114.49 | 3558.69±555.18 | 1806.27±218.16 | 26.3±10.32 | 65.57±13.52 | 2.04±0.34 | 8.51±1.51 | 166.34±12.72 | 3.25±0.37 | 149.46±66.12 | 8.53±0.13 | 19.57±1.95 |
| W | 31.00±8.98 | 1029.4±157.67 | 3715.82±568.69 | 1833.82±263.33 | 30.2±10.20 | 71.18±4.63 | 1.95±0.46 | 9.94±1.24 | 167.86±16.99 | 3.26±0.36 | 224.59±64.34 | 8.68±0.10 | 20.19±2.45 |
| WR | 31.04±10.50 | 1014.4±154.58 | 3647.37±574.75 | 1840.55±256.01 | 31.6±11.63 | 68.59±5.43 | 2.06±0.41 | 9.25±1.33 | 168.68±15.11 | 3.33±0.50 | 206.00±70.56 | 8.57±0.12 | 19.92±2.42 |

**Chapter 2**

**Cultivation Practices:**

At the beginning of the growing season, the soil was finely plowed using the disc plow to make pulverized soil tilth. Then the cotton was planted continuously in rows spaced 1 meter apart. (variety) Both irrigated and dryland plots received irrigation after seeding to maintain uniform initial soil moisture. Later during the growing period, only irrigated plots received irrigation through subsurface drip lines incorporated beneath every row. A total of 8.60 inches of irrigation water was added for the growing season. A few days after planting, we applied multispecies grasses residue (Bermuda grass, bluegrass, fescue) at the rate of 3 kg/m2 to the subplots having residue treatment. The weeds were periodically removed using a knife to keep the field weed-free.

**Harvesting and measurements:**

The crop was harvested in late October when most bolls was fully open. All the plants within 1m \* 1m subplots were considered for harvesting. The seed cotton was manually harvested by hand picking. Seed cotton from each plot was harvested into a separate plastic bag and weighted using digital balance. The lint yield was estimated using seed cotton weight assuming that the seed cotton contains 35 % lint by weight. We also recorded number total number of plants per subplot and number of bolls in each plant.

The aboveground plant parts were harvested from each subplot using the pruner and air dried for 2 weeks before taking dry weight. We used soil cores (3cm diameter, 10 cm length) to take root samples. Three plants were randomly selected within each subplot and two cores of soil (one from each side of a plant) were collected. Soil was collected from 3-5 cm away from plant stem. Therefore, total six cores of soil were collected from a subplot and pooled together into a plastic bag. We separated roots from the soil using 2 mm sieve and discarded the roots that passed through the sieve. The larger soil aggregate, stones and other residues were removed from the root samples, air dried roots for few days, and dry weight is recorded as belowground biomass.

Harvest index was calculated using the following equation.

Statistical analysis

Multilevel model (linear mixed effects model). Block and plot as Nested random effects.

Lme function (Lme4 package) R

Time series data – crossed random effects.