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Using the PT model to determine appropriate management for maize production. A case study of Fulwe Village in Morogoro District for Morogoro District.

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# Using the PT Model to Determine Appropriate Water Management for Maize Production: A Case Study of Fulwe Village in Morogoro District

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## Background

Fulwe village is located in Mikese ward, some 30 kilometres east of the Morogoro Municipality, along the Morogoro - Dar es Salaam highway. It is located at longitude 37º53’60’’ East, and the latitude is 6º46’ south. The annual rainfall ranges from 700mm to 1000 mm. The short rainy season (Vuli) starts in mid-October and ends in December while the long rains (Masika) start in February and ends in mid May. The dry season extends from June to October. The annual average maximum and minimum temperatures are 26ºC and 21ºC respectively. Soils are acidic *lithosols* and *ferralitic latosols* with deeper deposits of *ferruginous* sandy clay. Fulwe villagers depend mostly on rainfed agriculture and maize is the main staple food and also one of the major sources of income. Other crops cultivated include beans, soybeans and horticultural crops.

Farmers in the village have been facing a problem of good and poor maize yields even in the same season. The reasons for the mixed results were not well known by the agricultural extension officers serving the area. Some of the reasons that were being cited include inadequate crop husbandry, non-use of certified maize seeds and improper planting dates. The agricultural extension officers thought the problems were related to improper planting dates. That is the variable yields among farmers were caused by some farmers planting at the start of the rainy season and some in the middle and others very late in the rain season. It was noted from the agricultural extension officers that they were unable to successfully advise farmers on proper planting dates. In some cases they advised farmers to plant once the rain started, but still farmers ended up with lower yields compared to those who planted a bit late. The main issue that confronted agricultural extension officers, was therefore on finding tools or methods that will assist them in identifying a proper planting window for farmers in Fulwe village.

It is against this background that the PT Model, which is an agro-hydrological software, was therefore identified by the agricultural extension officers as a tool that could assist in the identification of the proper planting window by simulating maize yields for different planting dates in Fulwe village.

## Description of the PT Model

PARCHED-THIRST stands for **P**redicting **A**rable **R**esource **C**apture in **H**ostile **E**nvironments **D**uring the **H**arvesting of **I**ncident **R**ainfall in the **S**emi-arid **T**ropics. PARCHED-THIRST model is a user-friendly, process-based model, which combines the simulation of hydrology with growth and yield of a crop on any number of distinct or indistinct runoff producing areas (RPAs) and runoff receiving areas (RRAs). It is a distributed model, which simulates the rainfall-runoff process, soil moisture movement and the growth of sorghum, rice, maize and millet in response to daily climate data. The model includes the simulation of rice and macro-catchment systems up to the hillside or small catchment scale. The schematic diagram of its components is shown in Figure 1.

The model allows the user to enter dates for the start of the seasons (*Vuli* and/or *Masika*) and for the sowing dates. Alternatively the software itself can determine the best planting date. Furthermore, the software provides daily outputs of soil-moisture values for different layers of soils, dry matter accumulation, grain filling and other variables.

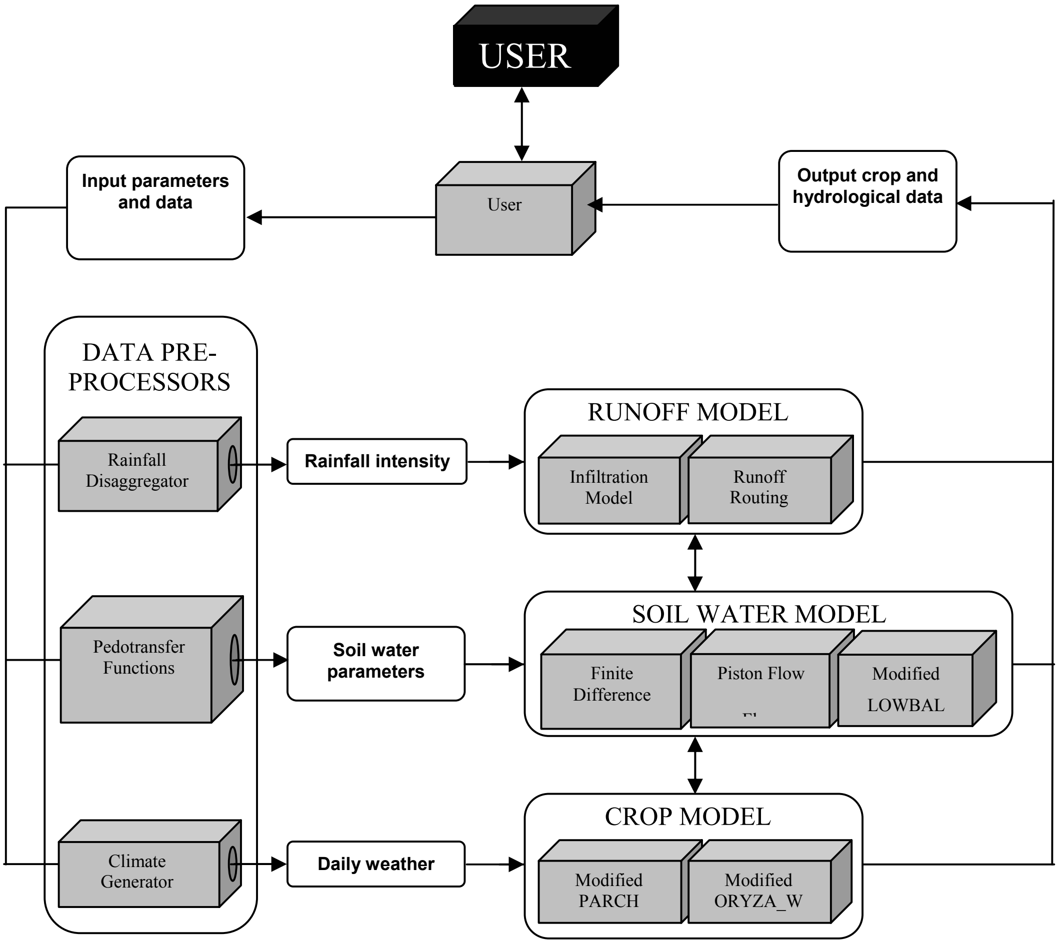


**Figure 1**: Interaction between the components making up the PARCHED-THIRST model.

**Objectives of the study**

The main objective of the study was, to investigate the reasons for poor maize yield and determine the appropriate management options that can improve maize production in Fulwe village, Morogoro district.

The specific objectives included the following:

- To investigate the effect of planting dates on maize yield in Fulwe village using the PT Model.

- To simulate the effect of rainfall pattern on dry matter and on grain accumulation using the PT Model.

## Methodology

The main method employed in studying the problem was yield simulation using PT model. This method was supplemented with field visit by agricultural extension workers and PT Help office staff. The field visit assisted in understanding the problems faced by farmers in the village.

**Field visit**

Before the visit, the agricultural extension officers organized a village meeting with Fulwe village farmers. The meeting was attended by village leaders and village extension workers in addition to agricultural extension officers from the Morogoro and Mvomero Districts and staff from the PT Help office. Figure 2 below shows some of the farmers at Fulwe village in addition to researchers from PT Help office – Sokoine University of Agriculture, agricultural extension officers from Morogoro and Mvomero Districts and village extension worker outside Fulwe village office.

Figure 2. Fulwe village farmers

During the field visit, farmers were given opportunities to express the problems they are facing with regard to maize production (Figure 3). The farmers reported that, agriculture activities at Fulwe are seriously affected by poor rainfall, poor mechanization techniques, lack of certified maize seeds and soil salinity.

Figure 3: One of Fulwe village farmers explaining problems facing their Agricultural activities

**Input Data Collection**

Weather data were obtained from Kingolwira Prison weather station and covered the period from 1999 to 2004. The parameters collected were daily rainfall, maximum and minimum temperature, humidity, radiation, wind speed and evaporation. Before running simulations the data were formatted to the PT input standard. Soil profile data used was also taken from Kingolwira (because of similarity to the soils found at Fulwe and closeness to Fulwe village) and maize variety (TMV1) data was used.

**Data Analysis**

Simulations for different planting dates were run and summary and daily output files were saved in the PT output folder. Output parameters analyzed were daily, seasonal and cumulative rainfall, maize yield, soil moisture, dry matter accumulation and grain weight gain.

# Results and Discussion

### Rainfall Patterns

The important growing window for maize in Fulwe is between January and May. Figure 4 shows daily rainfall trend over the long rainy season for different years.

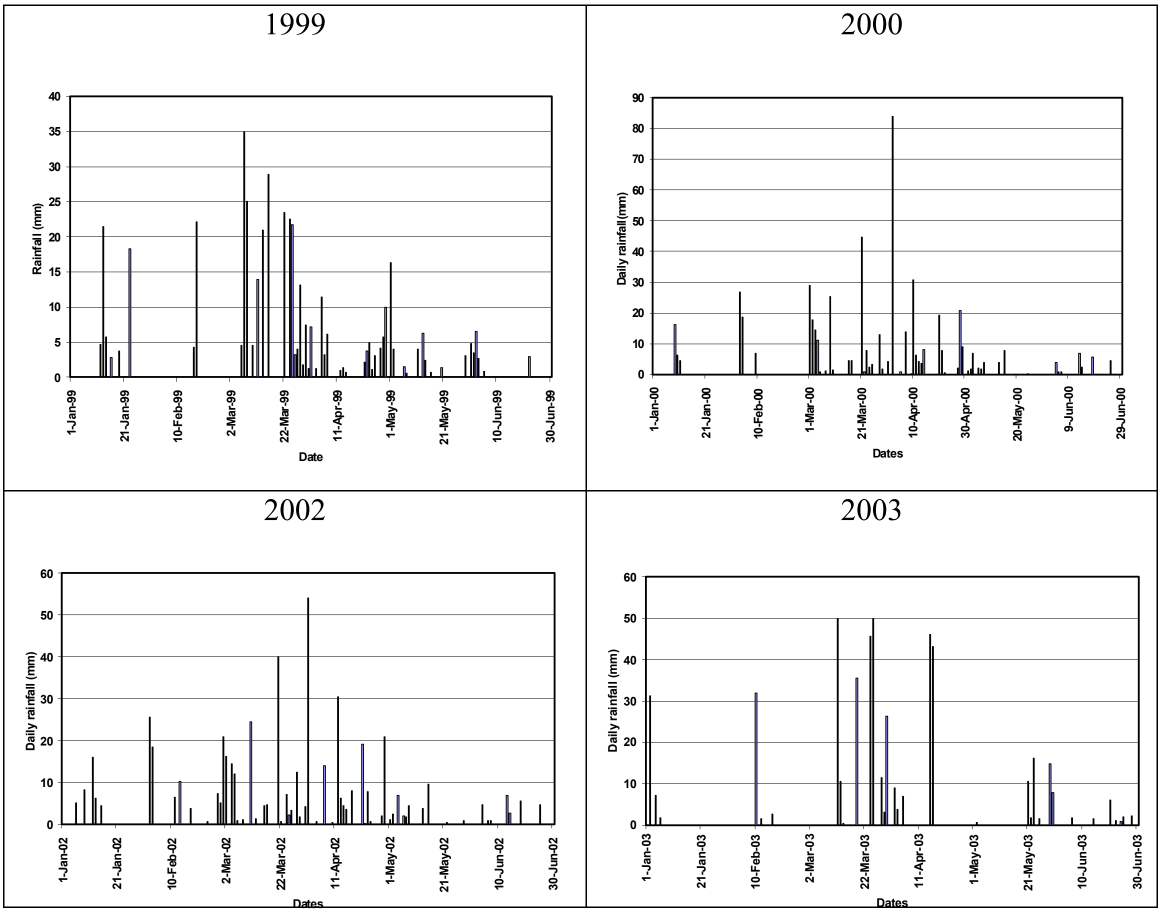


Figure 4: Daily rainfall patterns for the years 1999, 2000, 2002, and 2003.

These charts show a consistent pattern of dynamic two dry-spells between January and first week of March. Dynamic here means the actual dates of occurrence of the dry spells are not known. Farmers in Fulwe normally plant their maize between mid January and mid February. The dynamic dry-spells also means the start of the season is highly variable. It is therefore possible that some of the maize face moisture stress which affect the final yield. Furthermore, the area gets good rains between mid March and April.

There is poor rainfall in May in terms of low rainfall and frequent dry spells. These characteristics have a significant effect on the final yield because most of the grain weight accumulation occurs in May.

**Effects of planting dates on maize grain yields at Fulwe village**

Maize yield was simulated for different planting dates from 1999 to 2004. The results are summarized in Figure 6. The best planting dates that resulted with higher yields were between 20 January and 12 February. The average yields were between 0.45 and 0.49 t/ha and maximum yields ranged between 0.61 and 0.78 t/ha. However, the maximum yields were not occurring only on dates with maximum yield (around February 5) instead they occurred anywhere between 20 January and 12 February (a three-week window). With regard to simulated yields, the simulated maize yields agreed with those reported by farmers, which averaged between 0.5 and 0.7 t/ha. Therefore it was observed that planting dates might not be the primary or the only reason for the low yields. It was therefore necessary to carry out an analysis of dry matter accumulation.

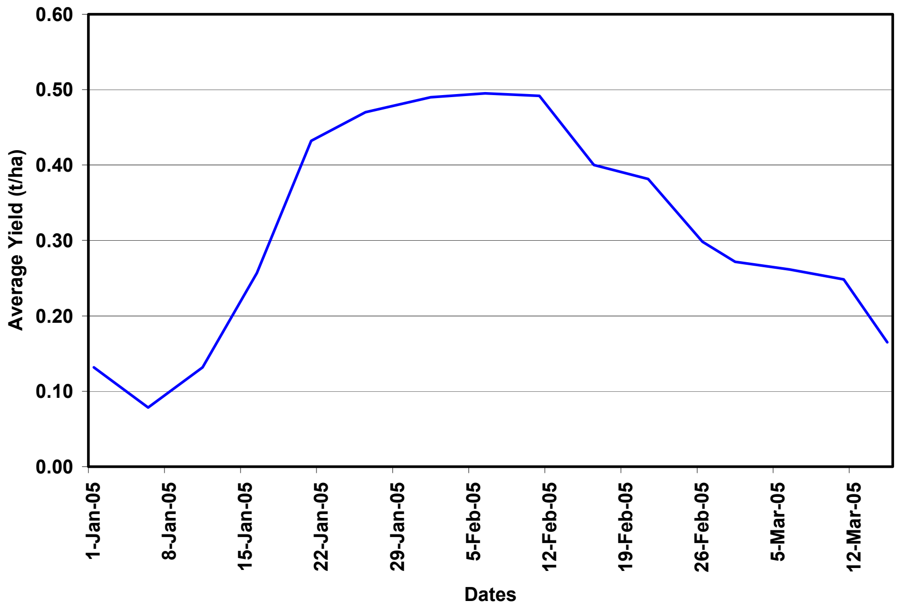


Figure 6: Average yields for different planting dates

**Dry matter accumulation**

Results of dry matter accumulation are shown in Figure 7 and Figure 8. The results indicate that dry matter accumulations at different planting dates were not significantly different for both 1999 and 2000. The same was observed on the other two years. Variation in dry matter accumulation from one year to another, which is normal, was observed in years 1999 and 2000. This was attributed mainly to the little amount of rainfall received in the year 1999. However, dry matter accumulation for 1999 was lower than that for year 2000 due to the following reasons:

- The year 1999 had both little annual and seasonal rainfall compared to year 2000. For example, the seasonal rainfall, as computed using the PT model, for 1999 was 441mm versus 514mm in 2000, while total annual rainfall was 761mm for 1999 versus 1011mm for 2000.
- The year 1999 had longer dry spells during the growing period as compared to that of 2000. For example, the year 1999-experienced dry spells of 16 days from February 18 to 5 March; while for the year 2000 there were only 5 days of dry spells within the same period.

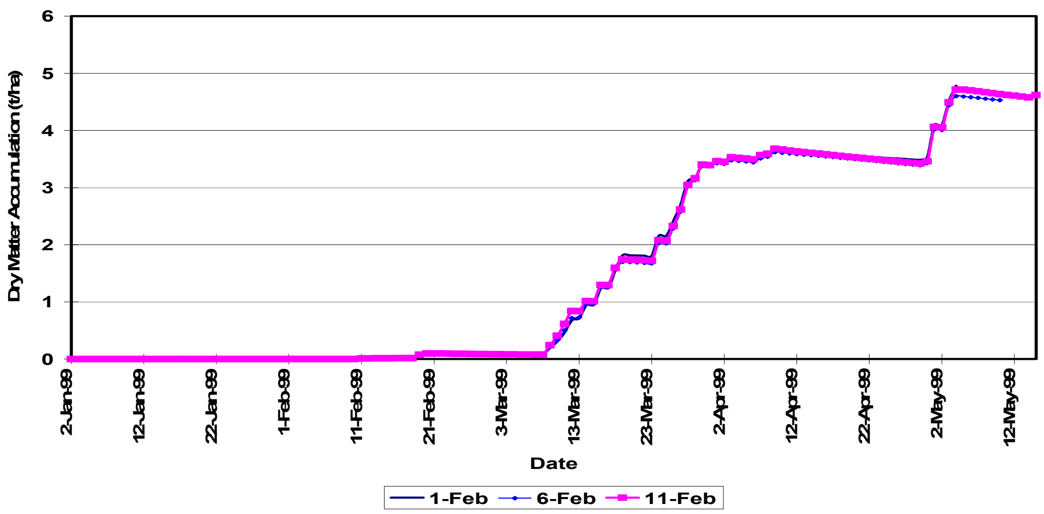


Figure 7: Dry matter accumulation in 1999

Since our interest was to assess if the different planting dates could affect the dry matter accumulation, the difference was not apparent or clear as shown in Figures 7 and 8. The science of crop development shows that a crop such as maize is not affected significantly by water stress, during its early days of growth. The most critical stage is at flowering and grain filling stages. This called for further investigations into the grain filling stage.

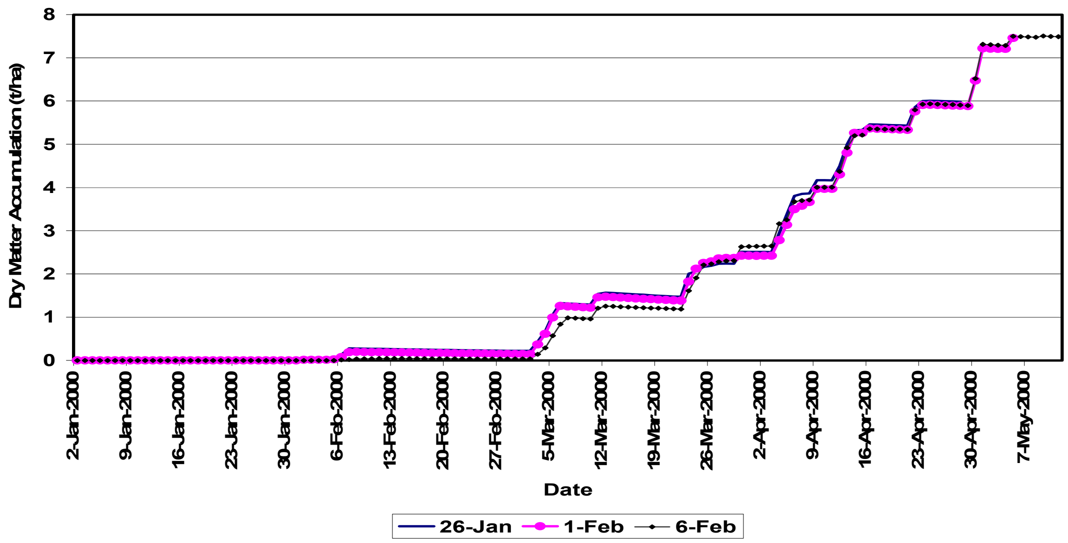

Figure 8: Dry matter accumulation 2000

**Grain weight accumulation**

For maize, and many other crops, grain filling stage is one of the critical periods for water requirements. Therefore availability of water at this period would increase partitioning of dry matter to grain leading to good crop yield. Since dry matter accumulation could not show the significant difference observed in the maize yield, analysis of grain weight accumulation was necessary.

Figure 9 and 10 show four maize grain filling charts for years 1999, 2000, 2002 and 2003 on a daily time step. Each chart has three lines representing three different planting dates. It is clear from the charts that each date responded differently. All charts have zero values up to late March or early April when the lines start to increase (grain filling start). The earlier the start of grain filling the earlier was the planting/sowing date. Therefore, the start of grain filling is fixed for a particular variety of maize. However, the start of the grain filling stage and subsequent days are very important to the final yield. For example, the comparison of grain filling rate for maize planted on 1st February and those planted on 6th February show that at the first few days of grain accumulation the maize planted on 1st February was being affected by very short dry spells compared to maize planted on 6th February. The grain filling was severely affected from 10th February because of a much longer dry-spell. The same dry-spell period showed that the rate of filling affected most the older plants than the younger ones since the growth rate of the maize planted on the 11th February was higher than that planted either on 1st or 6th February.

The second chart (year 2000) in Figure 9 shows a steady increase in grain weight compared to the 1999 chart, where the increase is step-wise. The steeper slopes for maize planted on 26th January and 6th February indicates a good supply of water during the start of grain filling. There was a dry-spell during the start of the grain filling stage for maize planted on the 1st February.

The 2002 chart in Figure 10 shows that all the lines are steadily increasing without any cross-over and the first line (21-Jan) having a steeper slope and therefore higher yield than the other two lines. Under normal circumstances, when the rainfall distribution is good even during grain filling stage, this is supposed to happen. The reason for the lower yields for the maize crop planted on 28th January and 1st February is the decrease in the rainfall amount toward the end of the rainfall season. This is contrary to the 2003 chart in Figure 10 because there is a cross-over between the 1st February and 11th February lines. The maize planted on the 1st February (1-Feb) suffered severe water stress at the start of grain filling stage. Maize planted on the 11th February (11-Feb) did not suffer water stress because the rainfall came on time such that the rate of grain filling was very high. The intersection of the grain filling lines was caused by the fact that the younger plants tend to have the highest growth rate compared to the older ones under the same and good environmental conditions (no water stress in this case). Therefore, when the water stress came, already the 11-Feb maize had achieved good yield and the 1-Feb grain accumulation had already been limited because of the previous dry-spell.

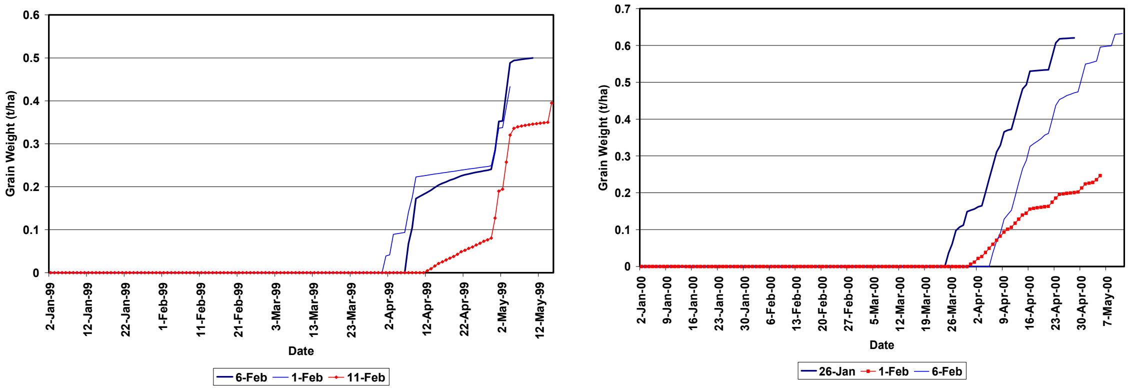


Figure 9: Maize grain filling for 1999 & 2000 season

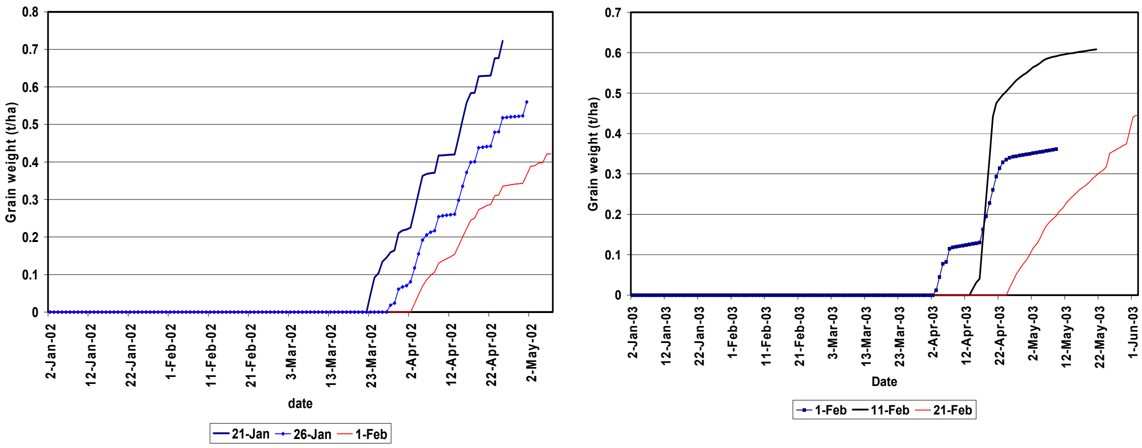


Figure10 Maize Grain filling for 2002 and 2003 seasons

Therefore, the low and variable maize yields that farmers were experiencing in the village were due to water stress during grain filling stage. Late planting also can result into lower yields if a normal rainfall pattern occurs, which means decrease in the amount of rainfall towards the end of the season.

## Conclusions and Recommendations

### Conclusions

- Given soil characteristics and weather data of Kingolwira prison weather station, it was possible to use the PT Model to determine appropriate management practices that could increase maize yields. The practices include among others, conservation agriculture and rainwater harvesting

- Dry matter accumulations for maize planted on different planting dates was not significantly different for any particular year.
- It was observed that grain weight (t/ha) differed for maize planted on different planting dates. The main reason leading to the differences were due to dry-spells during the grain filling stage.

## Recommendations

- Farmers at Fulwe village should practice conservation agriculture that will assist to conserve soil moisture.
- Also farmers should practice rainwater-harvesting (RWH) with storage techniques. The stored water can later be used at the grain filling stage, which is the critical stage of moisture requirements for maize crop.
- Further testing/ using the PT Model to investigate the cause of poor maize crop yields in other locations.

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