WHEAT CROP MODEL BASED ON WATER BALANCE FOR AGROMETEOROLOGICAL CROP MONITORING

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Abstract:

In this study effort has been made to develop a simple crop model based on water balance for crop monitoring. The main distinctive features of the model are, use of soil moisture at 30 cm depth, decadal water assessment for the wheat crop, an index value in percentage for each decade and for the whole season, which expressed the performance of the crop. The maximum cumulative seasonal index value 100 is apportioned equally into different decade required by the crop to complete its growth. Different stages are evaluated on the basis of water deficit/surplus experienced by the crop. The data used is on the basis of experiments conducted on wheat crop in the premises of the Barani University, Rawalpindi(33N°, 73E°), in research farms. The correlation exhibited between final yield and soil moisture index is about 98%, which is considered to be excellent value. The experiments were conducted from 1999 to 2004. The years 1999-2000, and 2000-2001 were found generally to be dry and growth of the crop faced water stress conditions. No sufficient moisture was available during all decades and drought stress occurred at vegetative, flowering and grain filling stages. This model is useful in rain fed areas and can give significant result.

Introduction:

Over the last thirty years important progress has been made in the establishment of the crop weather model in the world. In one way or another way, these models are intended to relate the effect of meteorological parameters e.g. temperature, pressure, rain, relative humidity etc to crop yield and production. A big drawback of statistical model is that often they are location specific and they give good results in average or near average conditions. It does not work properly during extreme weather conditions. Crop yield is the integrated effect of a number of physical and physiological processes that occur during the crop-growing period. These processes are influenced by the characteristics of the crop, weather, soil and time management factors. Several models have been developed and categorized (Sirotenko, 1994). Models in various fields like breeding, soil science, plant physiology, fertilizer response, insect damage and regional crop planning are used. A simplified model useful for operational purposes and able to asses the crop at any stage of the growth in rain fed areas of the North Punjab working on agro-meteorological data and crop data is always desired.

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Objectives:

The rain fed areas of Northern Punjab have been relatively neglected by the research efforts. Wheat is planted on more than 90% of cropped areas in Rabi season but average yields at 1.7t/hac are well below their potential. There is a need for research in barani areas of Pakistan to diagnose factors limiting productivity and to develop recommendations that can be adopted by formers to improve final yield.

Importance of Barani Areas:

Barani or rain fed areas make a significant contribution to agricultural production in Pakistan. Out of total crop areas of twenty million hectors about 5 million hectors (25%) are rain fed lands with no irrigation. In Punjab 20% of the cropped areas is rain fed (PARC/CIMMYT paper 90-2). The main soil in Barani areas have been developed from transported material such as alluvium and river alluvium. They are generally medium textured with a fair proportion of clay soils. Crucial factor in Barani areas wheat production is moisture conservation (Rain harvesting technique may be applied). Weed control is also important when there is sufficient rain in early crop stages.

Climatic variations in Research Area:

Rainfall is, of course, the critical factor for crop production; there is substantial year-to-year variation in rainfall. The variability in both rainfall and crop yields is higher for Rabi season (Nov- Apr) than for the Kharif season (sheikh et al 1988). The years 2001-2002, 2002-2003 and 2003-2004 were the best with regard to rainfall. The rainfall was evenly distributed throughout the crop season. The years 1999-2000 and 2000-2001 Rabi seasons were generally poor in terms of rain fall for wheat production.

Meteorological Observations:

Meteorological observations were recorded at 0800,1400 and 1700 (PST) with daily mean temperature(C°), relative humidity (%), rain fall (mm) and also the soil moisture at the depths of 5cm, 10cm, 20cm, 50cm,and 100cm were also observed. In addition to these pan evaporation (mm), dew duration (hour & minute), rainfall intensity (mm/hour), duration of bright sun shine (hour) and solar energy (cal/cm2/day) were also recorded at Regional Agro meteorological center Rawalpindi, Pakistan.

Research Farms:

This center started agro meteorological observations from 1988 in experimental farms of Barani Agricultural University Rawalpindi. Since then the activity is going on. The study was conducted on the experimental farms about 300m west of meteorological observatory. Field under observation was divided into four equal plots and overall ten plants were selected from each plot for phonological observation. These plants were tagged along a row in each plot. Phonological study was continued till harvesting.

Phenological Observations:

The following phases of crop were observed;

1. Emergence
2. Third Leaf
3. Tillering
4. Shooting
5. Heading
6. Flowering
7. Milk Maturity
8. Wax Maturity
9. Full Maturity
10. Harvesting

These phases were observed regularly almost three or four times in a week and in case of 50% occurrence of phase of selected plants, it was considered to be in phase and 75% occurrence was considered to be completion of the phase. Soil moisture sample were taken from each plots after about every ten days at 5, 10, 20, 30, 40, 50, 70, 90 and 110 cm depths. The soil moisture at 30cm depth is a critical stage for crop growth. Hence famous gravimetric method was employed in the calculation of soil moisture. This method is laborious but highly reliable.

Details of the model:

This method is based on the cumulative phenological duration crop water balance, which gives an index expressing the degree of water requirement satisfaction index (WRSI) (Reynold, C.A., 1998). Different components of water balance have been used. In this model soil moisture index is taken from the real data and it is not necessarally100% at the time of sowing. The water balance is the difference between precipitation received by the crop and water lost by the crop and soil. The water retained by the soil and available to the crop is also taken into account in the calculation. The calculation of the water balance is carried out on special form (FAO Agro meteorological rain fed crop monitoring)

Soil Moisture:

The soil moisture in percentage was calculated at the depth of 30cm by using gravimetric method.

The Number of rainy days (da)

The number of rainy days to give an idea of the distribution of rainfall during each phenological stage.

Evapotranspiration (ETo)

Climatologically records of temperature, vapors pressure, relative humidity, Sunshine duration and wind speed were used for the calculation of evapotranspiration on the daily basis.

Crop Coefficient (Kc)

To compute crop water requirement during each phenological stage, crop coefficient suitable to the crop stage need to be selected. For initial growth stage it is 0.3-0.4 and progressively reaches to 1.0-1.2(max) at flowering stages including roughly 20 days before and after flowering. The water requirements of the crop progressively recorded and crop coefficient decreased from 1.0-1.2 to about 0.4-0.5 at maturity stage.

Crop Water Requirement (WR)

The crop water requirement is computed by multiplying total value of ETO for each phenological stage with Kc.To calculate the total water requirements of the season from its beginning by summing up the successive water requirements of each crop stage.

Water Available (Pa-WR)

If (Pa-WR) is positive, it means sufficient moisture is available to the crop during that decade and if it is found negative the crop is considered to be under water stress during that decade.

Water Reserves in the Soil (Rs)

This term expresses the quantity of water existing within the rooting zone of the crop at a given stage, which can be readily utilized by the crop. The maximum quantity of useful water, which may be retained in the soil for a given crop, is “soil water retention capacity”.

Surplus and Deficit (S&D):

The water, more than storage in the soil appears as surplus in the S/D column. If the calculation comes to be negative figure, this was shown by minus sign in S/D column. Deficit refers to any quantity of water below the zero level of water retention capacity of the soil, called permanent wilting point (PWP). The notion of water deficit is very important for the calculation of water requirement satisfaction index (WRSI).

Cumulative Index (Is):

Thus considering surpluses and deficits, the actual ten days contribution were computed and added to get total cumulative seasonal value (Is) for the crop considered. The index (Is) thus expresses the extent to which the water regimes are favorable and therefore also indicates the performance of the crop in a season.

Seasonal Water Requirement (WR):

The comparison of soil moisture at 30 cm depth and water requirement calculated from the ETO (s) and crop coefficient (Kc) for each ten days is shown in figures 2, 3, 4, 5, 6. In these figures the series 1 indicates the water requirement and series 2 shows actual water available to the crop during each decade. The crop goes to deficit in the month of March and April, which affect the final yield. If at this stage crop is irrigated by some artificial means the final yield will be enhanced.

Yield Prediction:

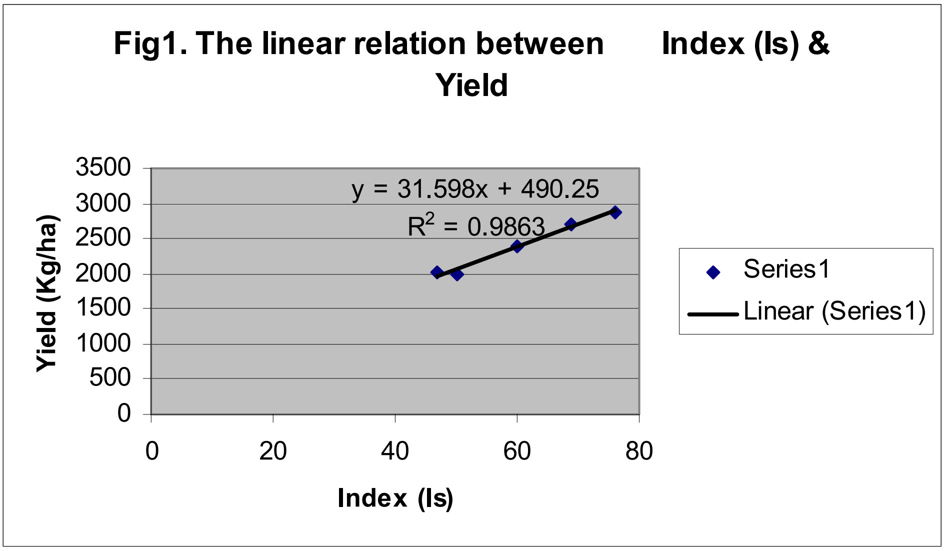
For wheat, computation of cumulative index (Is) for five seasons (1999 to 2004) with corresponding yields at different sowing dates, it is possible to develop a relationship between Is and yield (Y). This relationship forms a simple model capable of predicting yield on the basis of Is value accumulated in a season.

The new crop water balance model proposed would be tested on the basis of shifting sowing date. Five sowing dates were 06Nov, 20 Nov, 30 Oct, 05 Nov, 05 Nov and crops were harvested after full maturity on 4 May, 30 April, 20 April, 08 May and 26 April respectively. The yields (Y) recorded for these dates were 2000,2025,2400,2694 and 2875 Kg/hac respectively. The soils of Rawalpindi (33N°, 73E°) has clay and its water holding capacity is 32%(mm). The cumulative index (Is) five different sowing dates for wheat along with dates of harvesting, yields are given in table-1.

The wheat crop undergoes stress in the first decade of March during the seasons 1999-2000 and 2000-2001, shown in the figures 2&3. This is the period of flowering and grains forming. The years 2001-02 and 2003-04, figures 4 &6, shows no stress during the whole growth period. The crop observed a little bit stress during the year 2002-03, figure 5, in last decade of March, which did not affect the final yield. The reduction in the yield is being due to the water stress. The crop faces water stress during the flowering and grain filling stages. The graphical representation between cumulative index (Is) for five different sowing dates of wheat and corresponding yield (Kg/hac) is exhibited in figure-1, which is a straight line.

Table-1: Seasonal index (Is) according to new model for five different date of sowing of wheat with harvesting dates and yield

No	Date of sowing and harvesting	Cumulative index (Is)	Yield (Kg/ha)
1	06Nov-04May	50	2000
2	20Nov-30April	47	2025
3	30Oct-20April	60	2400
4	05Nov-08May	69	2694
5	05Nov-26April	76	2875



Conclusion:

The crop water balance at 30 cm depth with various components was developed. It exhibited excellent correlation which is r = 0.99 between the yield (Y) and the seasonal index (Is). R2 =0.986 the regression equation between the Is and yield is Y= 490.25+31.59Is, can be used to predict season crop while Is value can be used to exhibit crop performance or crop condition in the season. This model was tested with previous data and it gives results satisfactorily.

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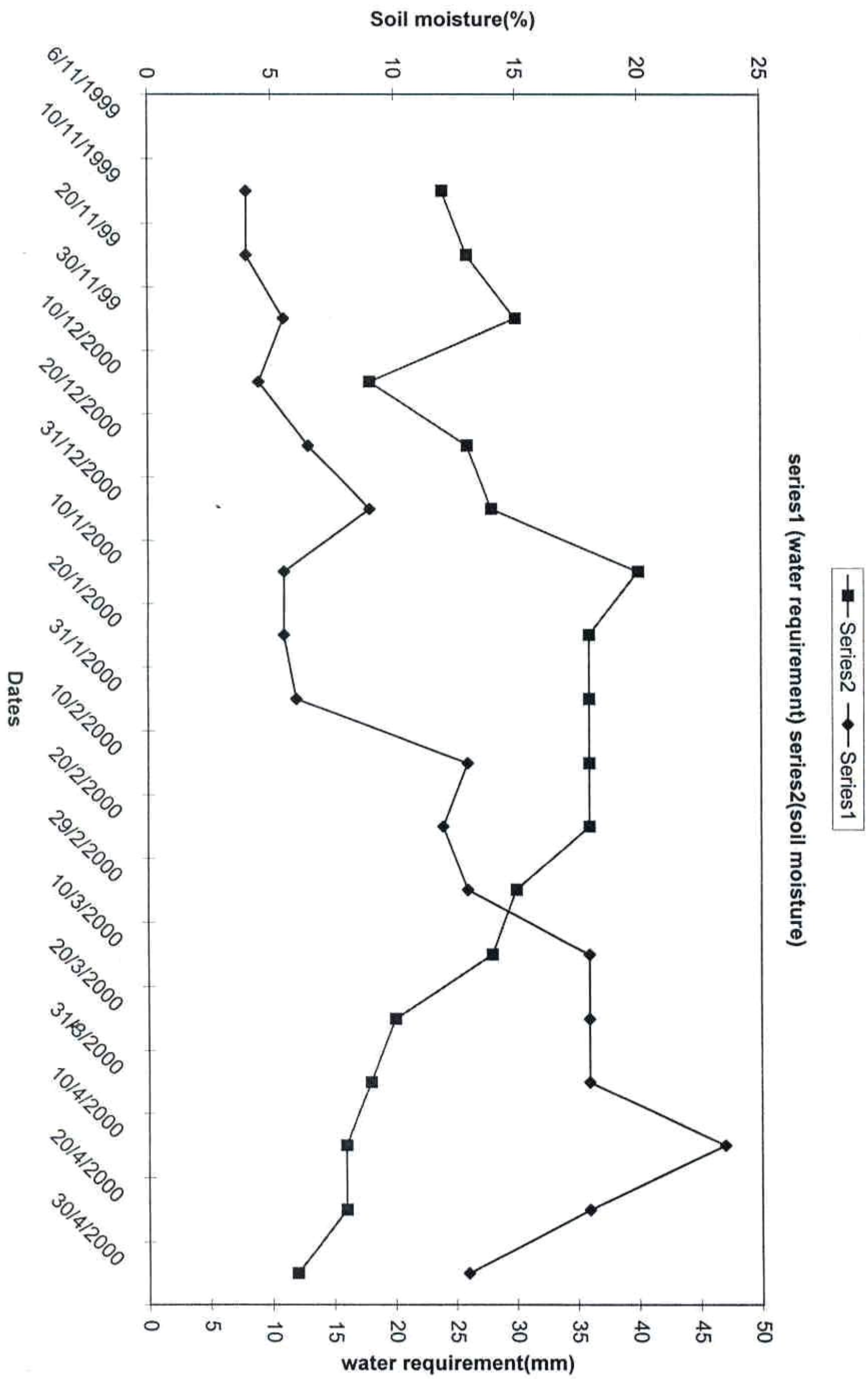
Fig-2: Comparison of soil moisture and water requirement for 1999-2000



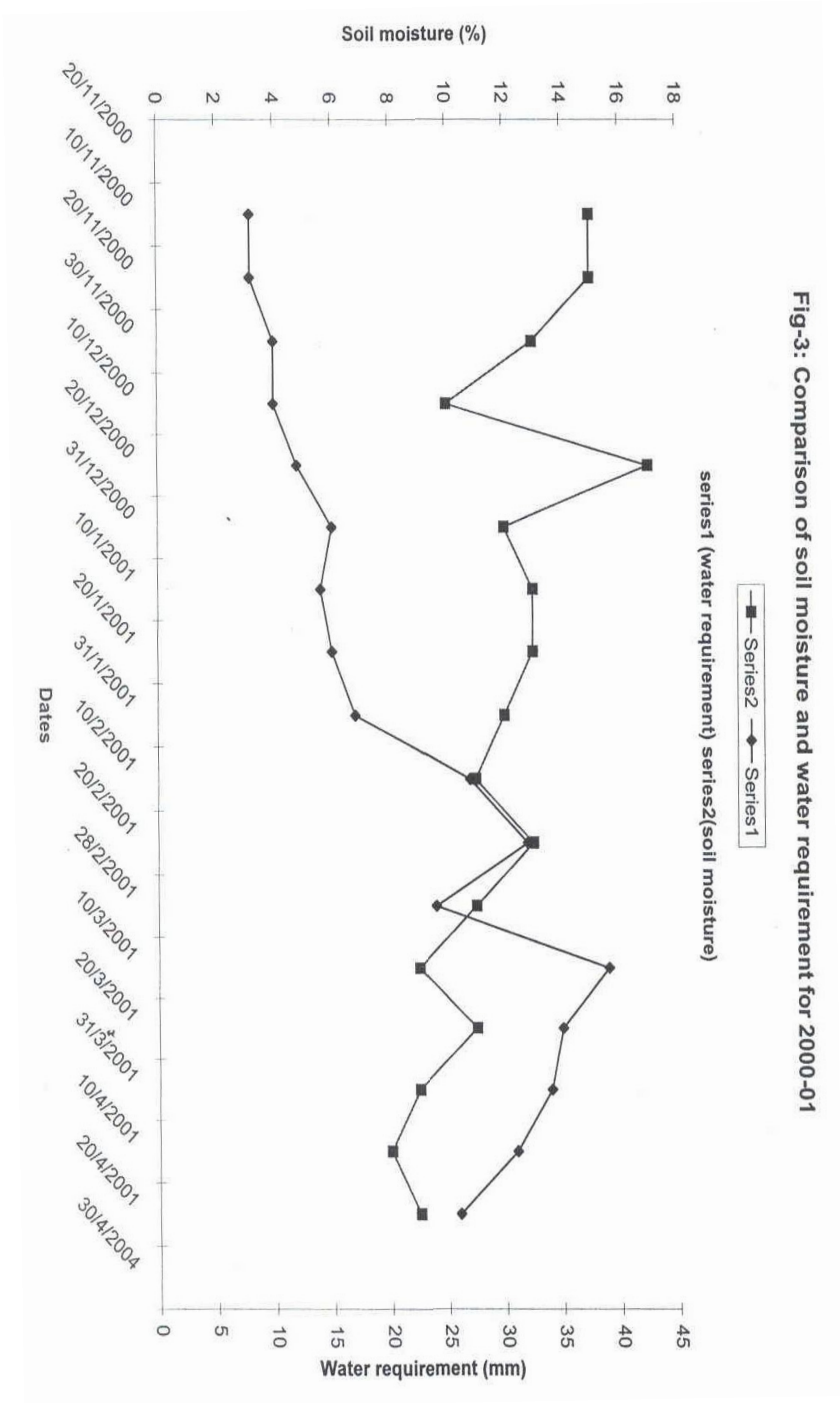


Fig-3: Comparison of soil moisture and water requirement for 2000-01
series1 (water requirement) series2(soil moisture)
Series2
Series1
Soil moisture (%)
0
2
4
6
8
10
12
14
16
18
Water requirement (mm)
0
5
10
15
20
25
30
35
40
45
Dates
20/11/2000
10/11/2000
20/11/2000
30/11/2000
10/12/2000
20/12/2000
31/12/2000
10/1/2001
20/1/2001
31/1/2001
10/2/2001
20/2/2001
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10/4/2001
20/4/2001
30/4/2004

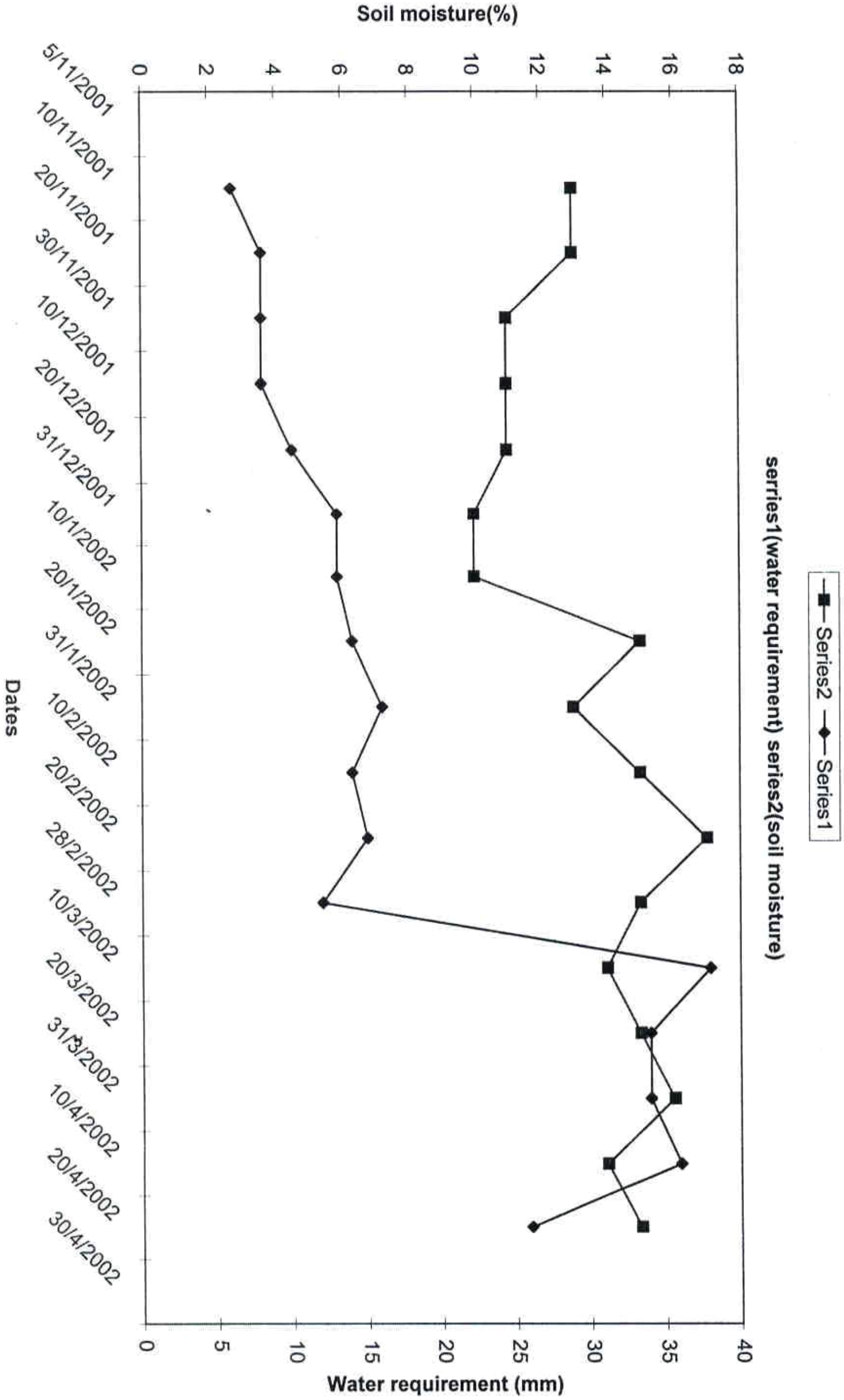

Fig-4:Comparison of soil moisture and water requirement for 2001-02

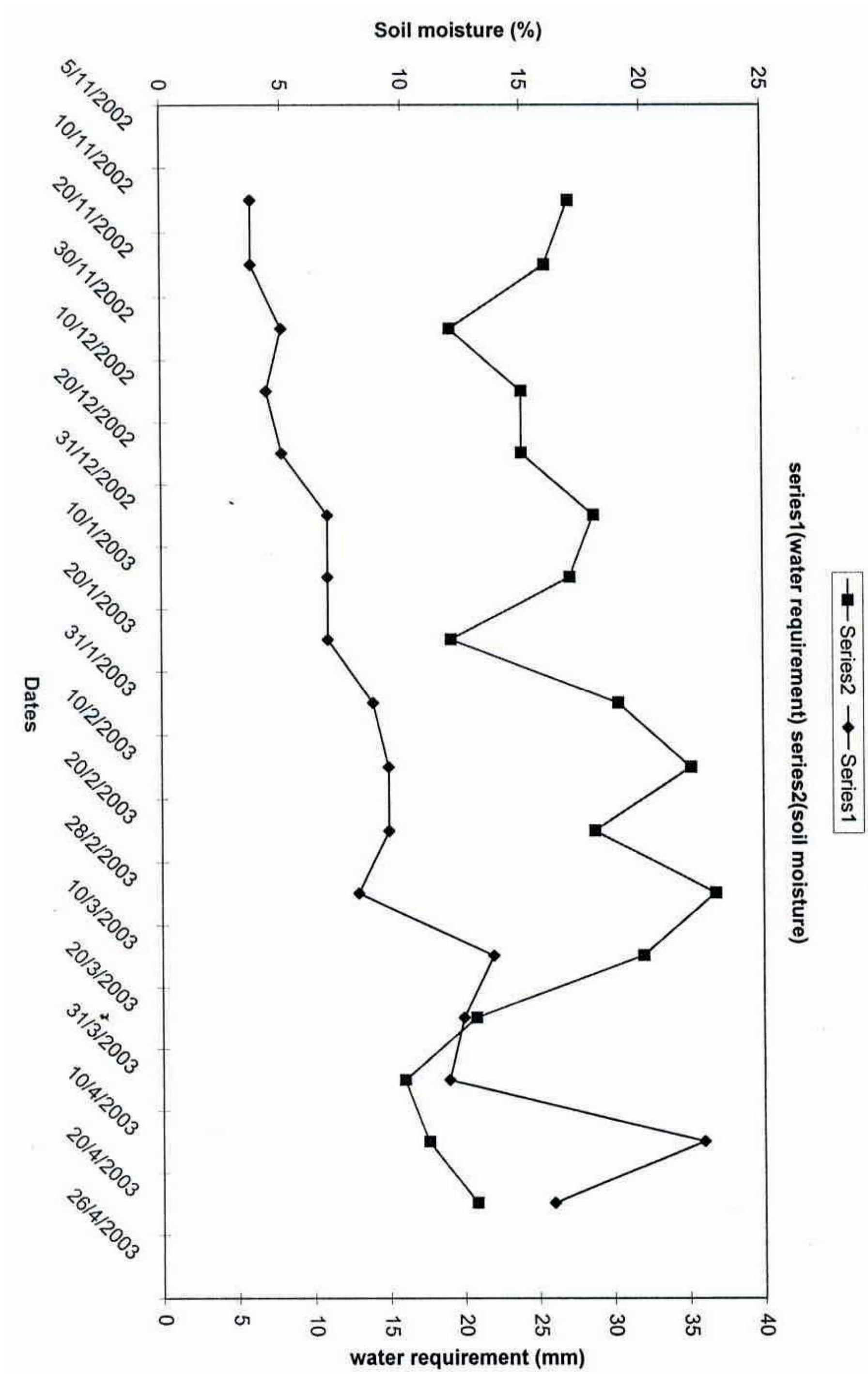

Fig-5: Comparison of soil moisture and water requirement for 2002-03

Fig-6: Comparison of soil moisture and water requirement for 2003-04