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Water management for potato crop (*Solanum tuberosum*) under scarcity conditions

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Abstract
The increasing global demand for food and other agricultural products calls for urgent measures to increase crop production per unit land used and per unit of water applied. The reported study was carried out at the experimental site of Central Research Field of Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, India. Soil moisture content was measured using gravimetric method periodically in 0-15, 15-30, 30-45, 45-60 and 60-75 cm soil profiles. Field experiments were conducted on Potato crop (Kufri Badshah) during 2020-2021 and 2021-2022. The crop was sown in last week of November and first week of December and was harvested in the last week of March spanning 112 days and 109 days during 2020-21 and 2021-22 respectively. Five irrigation treatments were maintained based on the maximum allowable depletion (MAD) of available soil water. The treatments were 15% (T_1), 30% (T_2), 45% (T_3), 60% (T_4) and 75% (T_5) maximum allowable depletion of available soil water. No water stress was maintained at the initial stages of the crop development in order to allow the plants attain a healthy growth. Field experiments revealed that irrigation schedule with 45% maximum allowable depletion of available soil water gives the maximum water use efficiency for Potato crop. It was found that for scheduling of irrigation for Potato crop 0-30 cm soil profile should be considered as most of the water was found to be extracted from this layer by the plant.

Keywords: Water management, potato crop, scarcity conditions

Introduction

Currently there are about 250 million hectares of irrigated land worldwide, most of which utilizes surface irrigation. Although irrigated land constitutes only 17% of the total agricultural land, it produces 36% of the world's total food requirement (Kashyap and Panda, 2002) [7]. The water requirement varies widely from crop to crop and also during the period of growth of individual crop (Doorenboss and Pruitt, 1977) [2]. In case of situations where water supply is limited, the irrigation demand of the entire cropping pattern cannot be met fully (Kashyap *et al*., 2014) [10]. In these conditions, deliberate under irrigation, also known as deficit irrigation can play a major role (Iqbal *et al*., 1999) [5]. By deficit irrigation, crops are purposefully under irrigated during plant growth stages that are relatively insensitive to water stress as regards to the quality and quantity of the harvested yield (Musick, 1994) [13]. Identifying growth stages of a particular cultivar under local conditions of climate and soil fertility allows irrigation scheduling for both maximum crop yield and most efficient use of scarce water resources (Doorenbos and Kassam, 1979) [3].

Potato is one of the most popular crops throughout the world. Present production in India is about 53.03 million tonnes from 2.16 million hectares area (Kashyap and Panda, 2001) [6]. It thrives well in all soil textures that have good internal drainage. It is relatively sensitive to soil water deficits. Potato needs frequent irrigations for its good growth and yield (Rangarajan, 2000) [15]. In some studies it has also been noticed that the potato crop is very sensitive to excess rainfall (Kashyap *et al*., 1997a) [9] and drought conditions (Kashyap *et al*., 1997b) [8].

With these background considerations a comprehensive field investigation was undertaken on a silty clay loam soil at the experimental fields of Central Research Field of Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, India. The experimental crop cultivar Kufri Badshah of potato was selected, which is a popular variety of the region. The effects of various scheduling of irrigation on the profile soil water status, crop yield and water use efficiency were studied. Irrigation schedules were based on 15, 30, 45, 60 and 75% maximum allowable depletion (MAD) of available soil water (ASW). The major goals of the study were to investigate the effect of scheduling of irrigation on profile soil water status, yield and water use efficiency of potato crop.

Materials and Methods

The reported study was carried out at the experimental field of the Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, India (Fig.1). The experimental field is situated at 25.44° North and 81.85° East latitude and longitude with an altitude of 90 m above the mean sea level. The climate is typically sub-humid and sub-tropical. The maximum temperature reaches up to 47.9 °C in the summers and drops down to 1.5 °C in the winters. The average rainfall in this area is about 1100 mm per annum. Most of which generally occurs during monsoon season (Kumar *et al*., 2015; Kumar *et al*., 2017) [11-12]. The physical properties of the soil of experimental crop field used for potato crop are given in Table 1.

Table 1: Physical properties of various soil profiles of the experimental crop field

Soil depth (cm)	Particle size Distribution (%)			Bulk density (g/cc)	Saturated hydraulic conductivity (cm/day)
	Clay	Silt	Sand		
0-15	29.0	27.5	37.5	1.62	15.4
15-30	31.2	31.2	31.6	1.58	10.8
30-45	33.8	33.7	26.5	1.59	3.6
45-60	33.9	30.2	30.0	1.63	2.9
60-75	34.6	32.0	27.2	1.64	1.62

Field experiments were conducted on Potato crop which belongs to the family *Solanaceae*, genus *Annum* and species *tuberosum*. The cultivar Kufri Badshah was selected, which is a popular 90-110 days vegetable crop of the locality and suits to the prevailing climate of the region. Water deficits during the period of flowering have the greatest adverse effect on yield, whereas early vegetative and maturation periods are less sensitive (Doorenbos and Kassam, 1979) [3]. The first field experiment was conducted during the period of 9 December 2020 to 30 March 2021 (112 days) and the second experiment was conducted during 27 November 2021 to 15 March 2022 (109 days).

Field layout and experimental details

Potato was cultivated in a surface land of 80 m^2 area. The field was divided into 20 plots of 2 m x 2 m size. Farm Yard Manure (FYM) was mixed manually with top 10 cm of soil layer at the rate of 20 kg/ha, ten days before sowing, while the second dose at a rate of 10 kg/ha of FYM was applied approximately 30 days after sowing. The sowing was done at a spacing of 50 cm, row to row and 20 cm, plant to plant during both crop experiments.

Irrigation treatments and scheduling

The irrigation treatments during Potato growing experiments consisted of irrigation scheduling based on maximum allowable depletion (MAD) of available soil water (ASW) criteria, which is given as:

T_1 = 15% maximum allowable depletion (MAD) of available soil water (ASW)
T_2 = 30% MAD of ASW
T_3 = 45% MAD of ASW
T_4 = 60% MAD of ASW
T_5 = 75% MAD of ASW

Irrigation scheduling was based on the percentage depletion of available soil water in the root zone. The available soil water was taken as the difference between root zone water storage at field capacity and permanent wilting point. For estimating water storage the effective root zone of Potato crop was considered as 60 cm (Allen *et al*., 1998) [1], irrespective of growth stage. Using the data of soil moisture measured gravimetrically, the percentage depletion of available soil water in the effective root zone was estimated. The plots were irrigated using a hosepipe and a water meter to give the exact volume of water.

Data collection

In order to study water balance, crop response to deficit irrigation and water use efficiency, it was necessary to collect data on profile soil moisture content and the growth attributes of the crop under consideration. In order to assess the change in soil water balance, soil moisture was measured frequently in 0-15, 15-30, 30-45, 45-60 and 60-75 cm soil profiles. The moisture content of soil layers were measured gravimetrically.

Results and Discussions

In order to assess the depth and time variation of soil moisture under different scheduling of irrigation, soil moisture was measured periodically in 0-15, 15-30, 30-45, 45-60 and 60-75 cm soil profiles during both the experiments.

Depth and time variation of soil moisture

The temporal variations of soil moisture in the root zone and below the root zone of the experimental Potato crop are presented in Figure 2 and Figure 3. The figures reveal that the soil moisture experienced a cyclic temporal variation at all soil depths. This trend was observed irrespective of the level of irrigation (MAD level). The amplitude of this cyclic variation (Fig. 2) was higher in upper layers than in lower layers. In experiment 1, there was a rapid decline of soil moisture in 0-15 cm soil profile 95 days after sowing (DAS) to the end of growth period. The lower layers of 15-30, 30-45, 45-60 and 60-75 cm soil profiles also exhibited a gradual decline in that order upto the end of the growth period. The decline was quite slow in 60-75 cm soil profile. The amplitude of cyclic variation was more in 0-15 cm soil profile because most of the applied irrigation water was lost through evaporation from the soil surface beside the transpiration (Sah *et al*., 2019) [16]. In addition to this, a portion of the applied irrigation water percolated to the lower layers also. Since the frequency of irrigation was high under T1, plants extracted more water from the upper layers. Therefore, 15-30, 30-45 and 45-60 cm soil profiles did not exhibit much cyclic variation. This trend was observed in both the experiments (Pandey *et al*., 2010) [14].

In resemblance to the temporal variation of soil moisture under T_1, soil moisture in 0-15, 15-30, 30-45 and 45-60 cm soil profiles under 30% MAD (T_2) also exhibited cyclic pattern. The results are presented in Fig. 2. Continuous sharp declines of soil moisture in all soil profiles were observed on 95 DAS. The magnitude of cyclic variation was higher in 30-45 and 45-60 cm soil profiles as compared to similar layers of T_1 during both the crop seasons (Fig. 3).

High amplitude of cyclic variation was noted in all soil profiles of the root zone under 45% MAD (T_3). Since the irrigations were scheduled at 45% MAD, the plant roots penetrated deeper in search of water as it was not adequate in the upper soil layers. The temporal variation of soil water was observed to be similar during both the experiments. The temporal variation under T_3 exhibited cyclic pattern upto 95 DAS in 0-15 and 15-30 cm soil profiles during experiment 1, while 30-45, 45-60 and 60-75 cm soil profiles showed a gradual decline on 92 DAS. A similar trend was observed during other experiment also.

Considerable soil moisture fluctuation was observed under 60% MAD (T_4) schedule. All soil profiles exhibited discernible cyclic variation, with considerably low amplitudes in the lower depths as compared to those observed at upper depths. This was ascribed to the large volume of water applied at a time during irrigation.

The 60-90 cm soil profile tended to remain steady upto the last irrigation applied, after which it decreased only marginally during the remaining growth period. Soil moisture below the root zone (60-75 cm soil profile) of the experimental plots experienced minimum cyclic variation with time. A slight continuous decline was observed when irrigations were discontinued. This trend was observed during both experiments.

Crop water use efficiency

The crop water use efficiency was taken as the ratio of the fresh yield and the crop evapotranspiration. The results pertaining to water use efficiency of the Potato crop under different scheduling of irrigation during crop experiments 1 and 2 are presented in Table 2. It is evident from the table that the highest crop water use efficiency was attained when the irrigation was scheduled at 45% depletion of ASW (T_3). A rising trend of crop water use efficiency was noticed from T_1 to T_3 and after that it decreased for T_4 and T_5 as the irrigations were delayed. A similar trend was observed during both crop seasons.

Field water use efficiency

The field water use efficiency was estimated in terms of fresh yield obtained per unit of land used and per unit of water available to the field. The results shown in Table 2, revealed that the highest field water use efficiency was attained when the irrigation was scheduled at 45% depletion of ASW (T_3). Similar to crop water use efficiency, a rising trend of field water use efficiency was noticed from T_1 to T_3 after that it decreased for T_4 and T_5 as the irrigations were delayed. This trend was same during both crop seasons.

Table 2: Water use efficiency (WUE) of Potato crop under different scheduling of irrigation during experiments 1 and 2.

Expt. No.	Treatment No.	Fresh Yield (kg/ha)	ET mm	Irrigation (mm)	Crop – WUE (kg/ha/mm)	Field– WUE (kg/ha/mm)
1	T1	33750	254	372	132.87	90.73
	T2	32620	246	356	132.60	91.63
	T3	35000	258	320	135.66	109.38
	T4	32870	247	354	133.08	92.85
	T5	31500	240	346	131.25	91.04
2	T1	38750	254	412	152.56	94.05
	T2	44375	257	375	172.66	118.33
	T3	47500	264	342	179.25	138.88
	T4	36875	255	415	144.61	88.85
	T5	34375	248	402	138.61	85.51

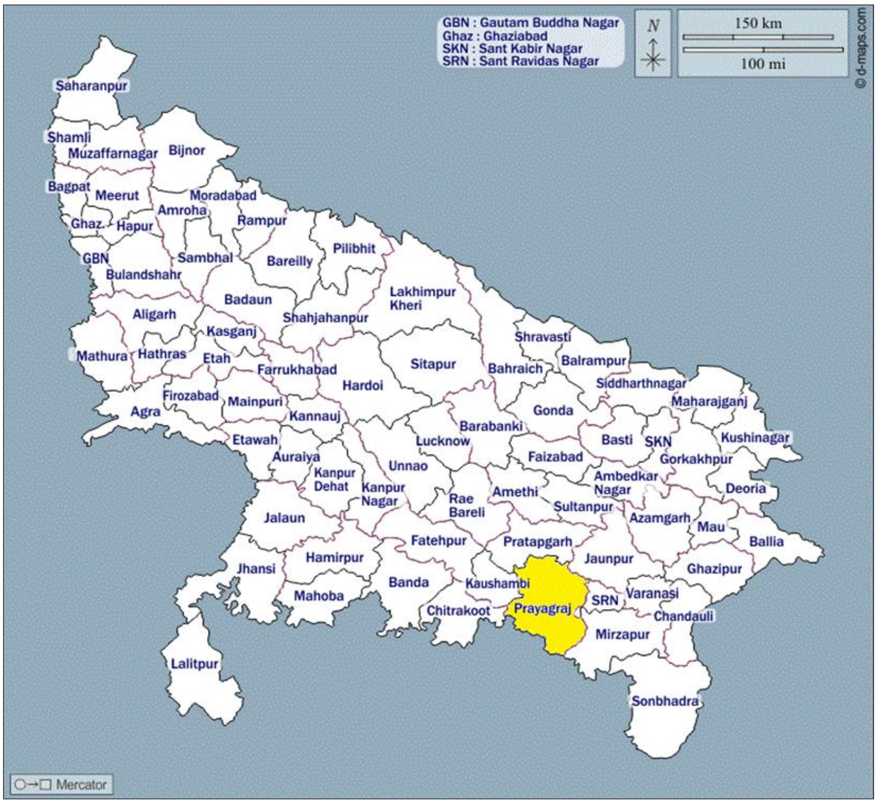

Fig 1: Location map of Prayagraj (Allahabad)

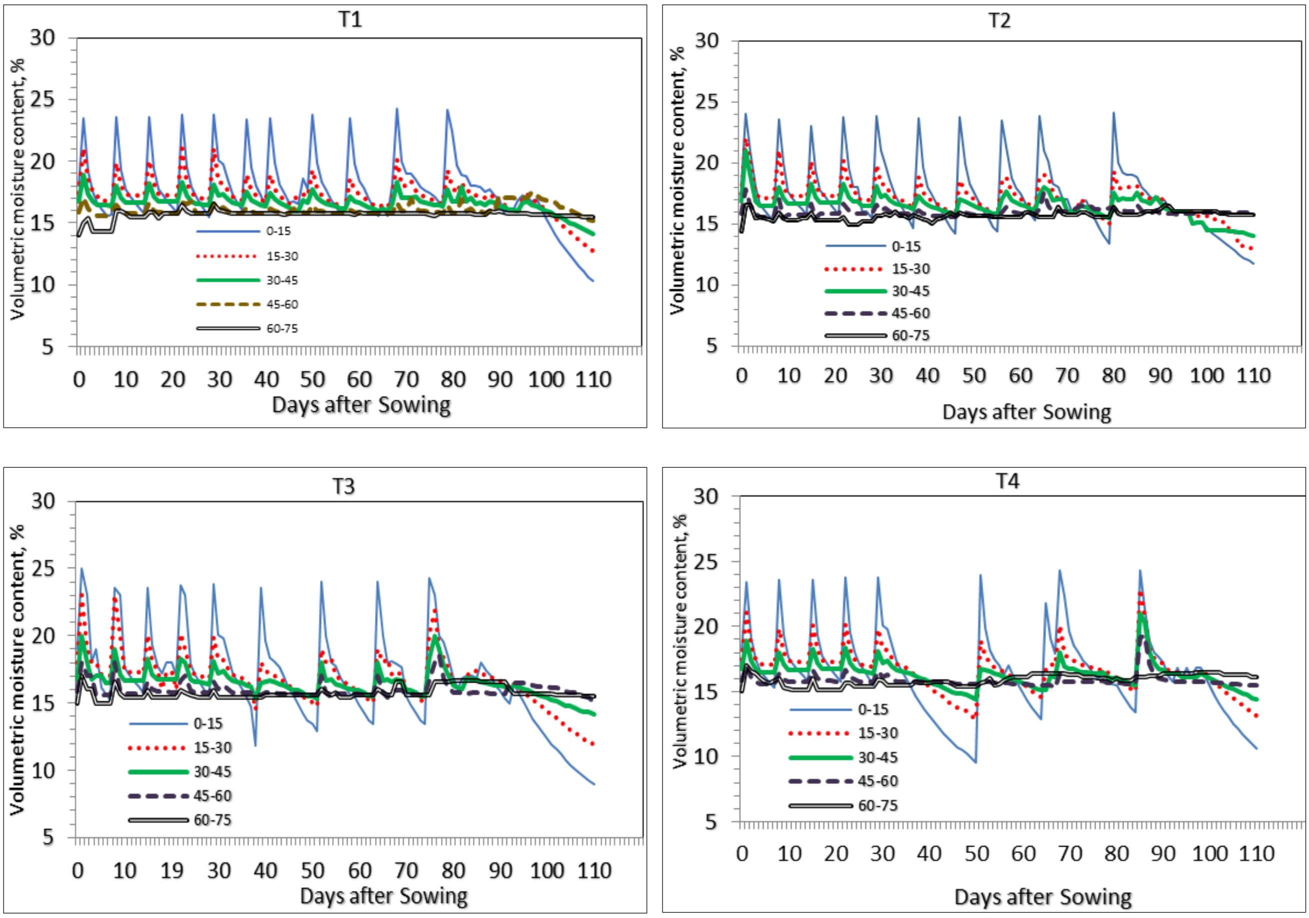

Fig 2: Depletion pattern of soil water within and below the root zone in potato crop field under different schedules of irrigation during experiment 1

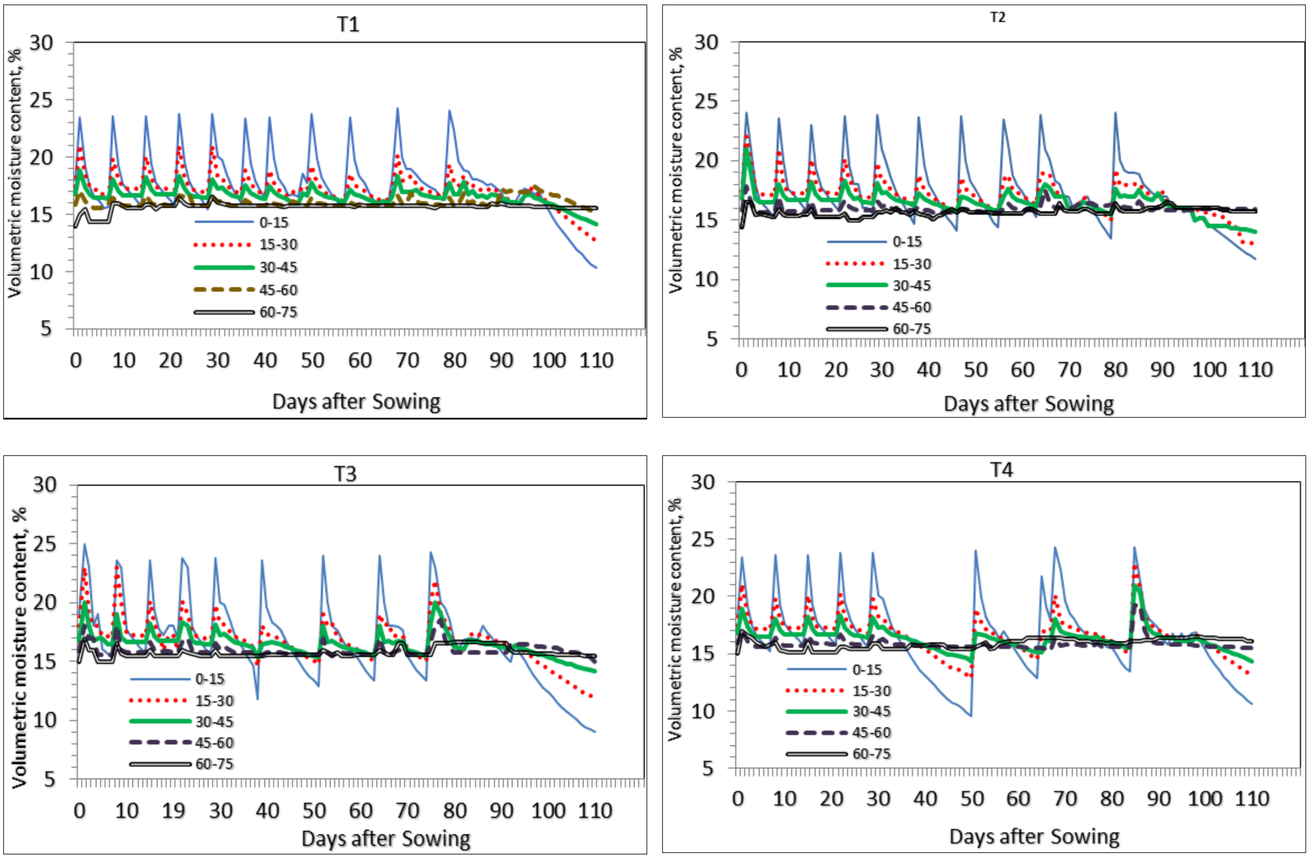

Fig 3: Depletion pattern of soil water within and below the root zone in potato crop field under different schedules of irrigation during experiment 2

Conclusions

The results of the study exhibited that under water stressed conditions, when soil water stress is imposed during non-critical stages of growth, the water scheduling requires some kind of planning. It was found that the irrigation is to be scheduled at 45% maximum allowable depletion of available soil water for potato crop grown in silty clay loam soils in a sub-humid and temperate region. A soil water stress of 45% MAD gives the highest crop water use efficiency as well as field water use efficiency. Only 0-30 cm of soil profile is to be considered for scheduling of irrigation for potato crop grown in a silty clay loam soils, since most of the water used by the crop is extracted from this layer.

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