**Mapping Crop Water Requirement of Potato using real time estimated evapotranspiration under Natural Farming Environment in North-Western Himalaya**

**Abstract**

Potato is a significant crop with wider prominence, supporting livelihood, food security and nutritional security to the global population. A field investigation was conducted at Zero budget natural farming farm of Department of Organic agriculture and natural farming, CSKHPKV, Palampur to evaluate the effect of sowing dates and irrigation regimes on potato growth and productivity. The present field investigation consisted of 3 sowing dates (10th November, 10th December and 10th January) and 4 irrigation regimes (Limited irrigation (two), Limited irrigation (three), Penman Monteith at 60% AWC (four) and Penman Monteith at 50% AWC (five)) which were evaluated in a randomized complete block design with three replications. The results of the present investigation revealed that sowing potato crop on 10th November resulted in the maximized plant height (40.2 cm), shoots per plant (2.88), dry matter accumulation per plant (1050.7 kg/ha), number of tubers per plant (5.04), average tuber weight (28.19 g) and tuber yield (125.5 q/ha) for the potato crop. Similarly, irrigation schedule based on Penman Monteith at 50% AWC involving 5 irrigation was the most suitable one for enhanced plant height (41.6 cm), shoots per plant (3.52), dry matter accumulation per plant (1028.1 kg/ha), number of tubers per plant (5.23), average tuber weight (30.01 g) and tuber yield (123.4 q/ha) for the potato crop. Therefore, sowing window of 10th November and irrigation schedule based on Penman Monteith at 50% AWC involving 5 irrigations can be recommended for the optimized tuber yield under conditions of North-western Himalayas of Himachal Pradesh.

**Keywords:** Crop Water Requirement, evapotranspiration, Natural Farming Environment, food security and nutritional security

**Introduction**

Potato is a significant crop with wider prominence globally after rice, wheat and maize. Potato supports livelihood, food security and nutritional security to the global population. Potato being a staple food crop in developing countries acts as a significant source of carbohydrates, proteins, vitamins and minerals (Khan et al. 2024). Potato has been cultivated over an area of 16.8 million hectares, production of 383 million tones and an average productivity of around 22 ton per hectare (FAOSTAT, 2025). Similarly, Potato occupies a significant place in Indian food system with cultivation over an area of 2.3 million hectare producing around 60.1 million tonnes of potato with an average productivity of 25.8 ton per hectare (FAOSTAT 2025). Despite of significant production, potato being a C3 crop is considered to be highly vulnerable crop to the ongoing threat of climate change in agro-ecosystems. Potato with an average optimum temperature range of 14-18 degree Celsius for optimized growth with substantial yield reduction above temperatures of 28 degree Celsius (Kirina et al. 2025). As global temperatures are expected to rise by 1.8 to 4 degrees Celsius by 2100, rising temperatures will play a significant limiting factor in influencing crop productivity (Rana et al. 2011; Rana et al. 2025; Salaria et al. 2024a). Rising temperatures along with variable and erratic rainfall, crop cultivation has been exposed considerably especially in rainfed countries like India with over 60 percent of rainfed area under rained cultivation (Rana et al. 2012, Rana et al. 2021; Mrabet et al. 2022).

Rising temperatures can severely influence sprouting, deformation and tuber formation for potato. The wider vulnerability of the crop can be attributed to shallow rooting system of potato wherein both drought and waterlogging conditions reduces potato tuber yield (Rai and Dong, 2025). Owing to rising temperatures substantial fluctuation in water resources has been advocated along with fluctuating rainfall trends in Himachal Pradesh (Rana et al. 2013a; Rana et al. 2014). According to a WOFOST crop model based study, potato yields could decline by 70 percent under various rainfall regimes such as short and long season rainfall patterns (Kirina et al. 2025). Therefore, to optimize potato tuber yields irrigation scheduling can be critical factor influencing potato productivity. Irrigation scheduling based on prevailing climatic conditions can be significant factor influencing crop water requirements and crop productivity (Rana et al. 2013b). Evapotranspiration based irrigation scheduling can help depict effect of climatic conditions on the potato growth and tuber yield (Badr et al. 2022). Irrigating potato crop irrigation regimes based on alternate root zone-based irrigation was found to reduce potato yields by 16.4 percent in China (Niu et al. 2024). Similarly, limiting irrigation levels by 50 percent under deficit irrigation regimes reduced potato tuber yield levels by 41 percent. However, applying the 50 percent of ET based irrigation resulted in 28 percent loss in tuber yield of potato (Badr et al. 2022).

Subsequently, along with evapotranspiration, optimizing sowing dates can be a significant factor influencing potato productivity. Early sowing of potato crop can result in exposure of crop to elevated temperatures at reproductive stage whereas lower temperature results in lowered biomass productivity and retarded tuber development. Kumar and his co-workers in 2023 evaluated the effect of planting dates on potato crop which revealed substantially higher crop yields with sowing of crop by 22nd of October in comparison to 8th October, 5th and 15th November (Kumar et al. 2023). Pathania et al. 2020 also emphasized the importance of optimizing sowing windows for enhanced crop productivity in wheat. Devi et al. 2024 evaluated the effect of sowing dates on maize yield and observed that optimizing the sowing dates (10th June) of resulted in maximized maize yield. Similarly, optimizing sowing windows (15th October) for wheat crop resulted in the substantially higher wheat yield levels especially under conditions of North-western Himalayas of Himachal Pradesh (Naik et al. 2024; Salaria et al. 2024b).

Altering sowing dates leads to change in exposure of crop to variable environmental conditions and ultimately influencing crop productivity. Keeping in consideration the effect of irrigation scheduling and sowing dates on potato productivity, the present investigation was planned to study the effect of various irrigation schedules and sowing dates on potato productivity under north-western Himalayas of Himachal Pradesh.

**Material and methods**

The field experiment was carried out at Zero budget natural farming farm of Department of Organic agriculture and natural farming. The experimental field was located at 32°07’ N latitude, 76°23’ E longitude at an elevation of 1290.8 m. The experimental site can be characterized for high rainfall, mild summers (temperature range of 19.0-31.0 °C) and severe winters (temperature range of 3.5 -13.4°C). During the cropping season, the average weekly maximum and minimum temperature varied from 10.9 to 31.3 °C and 2.1 to 18.3°C, respectively. The total rainfall, relative humidity and cumulative pan evaporation were 384.9 mm, 40.4 to 90.3 per cent, 641.2 mm whereas the monthly evapotranspiration and bright sunshine hours ranged from 58.2-126.6.5 mm and 4.5 to 9.1 hour. Soil properties for the experimental site were determined before the crop sowing wherein soil was having silty clay loam texture, available nitrogen, phosphorus and potassium were 268, 18.3 and 176.5 kg/ha. Crop history encompassed wheat and adzukibean cultivation for the recent *Kharif* and *rabi* cropping season. The field experiment was laid in a randomized block design involving 12 treatments with three replications. The treatment combinations were based on 3 sowing dates and 4 irrigation schedules wherein variety taken was *Kufri Jyoti.*The Natural farming practices were followed to raise the crop (Sharma et al. 2020; Sharma et al. 2023; Sharma et al. 2024, Rana et al. 2021; Mrabet et al. 2022). The seed tubers were cut into pieces of 30-50 g followed by seed treatment using *Bijamrita*. The crop was sown on treatment-based schedules i.e., 10th November, 10th December and 10th January. The crop was sown at a row to row and plant to spacing of 50 cm and 20 cm, respectively. The basal application of *Ghanajiwamrita* was done at the time of sowing, followed by foliar application of *Jiwamrita* at 14 days interval. Earthing up for potato was carried out on 15th January, 16th, 19th, 25th February and 22nd of March, 2021. Crop harvesting was carried out on 28th April, 4th and 9th May of 2021.

The data for plant height, number of shoots per plant, shoot dry matter accumulation per stem and number of tubers per plant was collected using standard procedures. The data was subjected to analysis of variance using standard procedures (Gomez and Gomez, 1984) for Randomized Block Design.

**Results and Discussion**

The study aimed to assess the influence of different sowing windows and irrigation scheduling (based on evapotranspiration) methods on the growth and yield attributes of potato under natural farming conditions. The results revealed significant variations in plant growth and yield components across sowing dates and irrigation treatments.

Among the sowing dates, the 10th November sowing resulted in superior plant performance compared to the 10th December and 10th January crop sowing. Plant height, root length, number of plants per square meter, number of leaves per plant, and leaf area index (LAI) were generally higher in early sowing, especially at 90 days after planting (DAP) and at harvest. For example, plant height at harvest was highest (40.2 cm) in the 10th November sowing, while it declined to 36.7 cm and 37.9 cm for the 10th January and 10th December sowings, respectively. A similar trend was observed for LAI, which peaked at 3.08 in November sowing and gradually declined with delayed planting. These results suggest that early sowing provided a more favorable environment for vegetative growth due to longer exposure to optimal temperature and solar radiation, resulting in better canopy development and resource use efficiency (Table 1).

Yield attributes followed a similar pattern. The number of shoots per plant, number of tubers per plant, average tuber weight, and total tuber yield per hectare were significantly higher in the 10th November sowing. The highest tuber weight for the potato crop was recorded for the 10th November sown crop followed by 10th December sown crop. Tuber yield was significantly affected by different treatments based on irrigation regimes and sowing dates. The yield obtained 125.5 quintals per hectare in the earliest sowing window (10th November), whereas it decreased to 103.1 quintals per hectare in the January (10th January) sowing. The lowest tuber yield for potato crop was observed for the 10th January sown crop. Similarly, among various irrigation regimes Penman Monteith at 50% AWC (five) based irrigation schedule resulted in the highest tuber yield for the potato crop at harvest followed by Penman monteith weather model at 60 % AWC (four) based irrigation schedule. The lowest tuber yield for the potato crop was observed for the limited irrigation regime based on involving two irrigations in the potato crop. The grades of tubers (>75 g and 50–75 g) were higher in early sowing reflecting the advantage of timely planting in achieving better productivity and marketable yield.

Tuber yield can be seen as cumulative output resulting from shoot dry matter accumulation per plant, average number of tubers per plant and their corresponding weight. Tuber yield may have primarily varied as per the carbohydrate accumulation in the potato tubers. Khan et al 2024 have also investigated the effect of sowing dates on potato yield wherein they observed that early planting was the suitable one for optimized tuber yield in potato crop, emphasizing the importance of sowing dates on potato production.

Amongst Irrigation scheduling based on ET methods also had a profound impact on crop performance. The Penman-Monteith method with irrigation scheduled at 50% available soil water content (AWC) produced the best results across all growth and yield parameters. Plants under this treatment achieved the greatest height (41.6 cm), the highest number of leaves per plant (14.14), and the maximum LAI (3.17) at harvest. The number of tubers per plant and average tuber weight were also superior, with values of 5.23 and 30.01 grams respectively. Consequently, the total tuber yield was highest (123.4 q/ha) under this regime, followed closely by the Penman-Monteith method at 60% AWC (120.9 q/ha). In contrast, the limited irrigation treatments (two or three irrigations only) led to significantly lower growth and yield performance, highlighting the stress experienced by the crop due to inadequate water availability during critical growth stages. (Table 1).

The findings highlighted the critical role of sowing time and scientifically based irrigation scheduling in optimizing potato productivity under natural farming systems. Early sowing in November, coupled with irrigation based on the Penman-Monteith method at 50% AWC, provided the most favorable conditions for maximizing both vegetative growth and tuber yield. These practices not only enhanced the physiological efficiency of the crop but also contributed to better resource utilization, making them suitable strategies for sustainable potato cultivation under organic and natural farming frameworks.

**Conclusion**

Based on the present investigation, it can be concluded that early sowing on 10th November significantly improved potato growth and yield under natural farming. Superior vegetative traits and yield attributes were recorded in early planting due to favorable climatic conditions. Among irrigation treatments, the Penman-Monteith method at 50% AWC produced the highest tuber yield. Limited irrigation led to poor crop performance, highlighting the importance of adequate water supply. Thus, timely sowing combined with optimized irrigation scheduling enhances productivity and resource use efficiency in potato cultivation under natural farming conditions in sub temperate climatic conditions of Himachal Pradesh.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | Plant height (cm) | | | Root length (cm) | | Number of plants/m2 | Number of leaves/ plant | | | LAI | | |
| 60 DAP | 90  DAP | At harvest | 90  DAP | At harvest | At harvest | 60  DAP | 90  DAP | At harvest | 60  DAP | 90  DAP | At harvest |
| **Date of sowing** | | | |  |  |  |  |  |  |  |  |  |
| 10th November | 15.2 | 27.8 | 40.2 | 33.37 | 54.35 | 10.49 | 4.1 | 10.6 | 12.4 | 1.51 | 3.08 | 2.73 |
| 10th December | 19.9 | 25.7 | 37.9 | 31.09 | 52.50 | 10.75 | 5.3 | 10.2 | 13.4 | 2.03 | 2.85 | 2.54 |
| 10th January | 20.3 | 24.4 | 36.7 | 29.48 | 51.28 | 10.32 | 5.7 | 9.9 | 13.5 | 2.21 | 2.76 | 2.29 |
| SE(m)± | 0.27 | 0.52 | 0.44 | 0.41 | 1.03 | 0.22 | 0.08 | 0.16 | 0.20 | 0.05 | 0.05 | 0.03 |
| CD (p=0.05) | 0.80 | 1.53 | 1.29 | 1.21 | NS | NS | 0.23 | 0.47 | 0.58 | 0.15 | 0.14 | 0.09 |
| **Irrigation scheduling based on ET Method** | | | | | | | | | | | | |
| Limited irrigation (2) | 16.5 | 23.5 | 34.1 | 29.46 | 48.52 | 10.33 | 4.18 | 9.10 | 12.21 | 1.64 | 2.59 | 2.29 |
| Limited irrigation (3) | 18.2 | 24.9 | 36.4 | 30.49 | 51.76 | 10.48 | 4.93 | 9.95 | 12.41 | 1.88 | 2.78 | 2.41 |
| Penman Monteith at 60%AWC (4) | 19.2 | 27.3 | 41.1 | 32.28 | 53.92 | 10.60 | 5.40 | 10.89 | 13.65 | 2.03 | 3.04 | 2.59 |
| Penman Monteith at 50%AWC (5) | 19.9 | 28.1 | 41.6 | 33.06 | 56.64 | 10.67 | 5.50 | 11.12 | 14.14 | 2.11 | 3.17 | 2.78 |
| SE(m)± | 0.31 | 0.60 | 0.51 | 0.48 | 1.19 | 0.26 | 0.09 | 0.18 | 0.23 | 0.06 | 0.05 | 0.04 |
| CD (p=0.05) | 0.92 | 1.76 | 1.49 | 1.40 | 3.49 | NS | 0.26 | 0.54 | 0.67 | 0.17 | 0.16 | 0.11 |

**Table :1 Effect of sowing windows and irrigation regimes on plant height, root length, number of plants and phenological stages of potato under Natural Farming**

**Table : 2 Effect of sowing windows and irrigation regimes on number of shoots/plant, average tubers and weight/plant tuber yield and grades of potato under Natural Farming**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | **Number of shoots/plant** | **Average number of tubers/plant** | **Average tuber weight(g)** | **Tuber yield q/ha** | **Grading**  **(q/ha)** | | |
|  |  |  |  | **>75g** | **50-75g** | **<50g** |
| **Date of sowing** | | | |  |  |  |  |
| 10th November | 2.88 | 5.04 | 28.19 | 125.5 | 125.5 | 22.5 | 68.3 |
| 10th December | 2.62 | 4.87 | 26.92 | 111.9 | 111.9 | 19.2 | 63.5 |
| 10th January | 2.38 | 4.73 | 25.38 | 103.1 | 103.1 | 17.7 | 58.8 |
| SE(m)± | 0.05 | 0.06 | 0.25 | 1.00 | 1.00 | 0.44 | 0.93 |
| CD (p=0.05) | 0.16 | 0.18 | 0.74 | 2.94 | 2.94 | 1.30 | 2.73 |
| **Irrigation scheduling based on ET Method** | | | |  |  |  |  |
| Limited irrigation (two) | 1.47 | 4.51 | 23.37 | 100.2 | 100.2 | 17.3 | 57.6 |
| Limited irrigation (three) | 2.30 | 4.69 | 24.68 | 109.6 | 109.6 | 19.1 | 61.9 |
| Penman Monteith at 60%AWC (four) | 3.21 | 5.08 | 29.27 | 120.9 | 120.9 | 21.2 | 66.7 |
| Penman Monteith at 50%AWC (five) | 3.52 | 5.23 | 30.01 | 123.4 | 123.4 | 21.9 | 67.2 |
| SE(m)± | 0.06 | 0.07 | 0.29 | 1.16 | 1.16 | 0.51 | 1.07 |
| CD (p=0.05) | 0.18 | 0.21 | 0.85 | 3.39 | 3.39 | 1.5 | 3.15 |