

Nutrient and water management for potato

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Potato being shallow rooted crop has relatively high demand for many nutrients and irrigation as the supply of nutrients and water from the soil alone is often not adequate to meet the crop demands for growth. Best yields can be obtained with optimum management of both nutrients and water. Hence, ensuring a sufficient supply of nutrients and maintaining optimum moisture is crucial. The crop is sensitive to moisture stress and most of the studies have indicated stolon initiation followed by tuberization as the most critical stages for potato. Soil moisture monitoring tools like tensiometers and cumulative pan evaporation (CPE) based irrigation scheduling help in economizing the water use. Adopting micro-irrigation can save 40-50% irrigation water.

Keywords: Micro-irrigation, Nutrient management, Potato, Soil moisture

POTATO is one of the world's most important non-cereal food crop being cultivated in almost all the states of India under different agro-climatic conditions. Potato being shallow rooted crop has relatively high demand for many nutrients and irrigation as the supply of nutrients and water from the soil alone is often not adequate to meet the crop demands for growth. The yield of a potato crop is mainly determined by its specific genetic background i.e. cultivar being grown and management factors. Amongst different management factors, ensuring a sufficient supply of nutrients and maintaining optimum moisture is crucial. Soil moisture affects the nutrient availability and controls the leaching of nutrients. Therefore, a comprehensive nutrient and water management program is essential for producing a profitable, healthy and quality potato crop without causing damage to the environment. Role of nutrients and water management, their impact on crop for profitable yield, are discussed here.

Nutrient management

Seventeen nutrients are considered essential for plant growth. Essential elements have been and grouped as primary, secondary and micronutrients according to their relative amounts needed by plants. Primary nutrients are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P) and potassium (K), also known as macronutrients and are required in the largest amounts. Compared to the primary essential nutrients, secondary nutrients are usually needed in moderate amounts. The secondary nutrients are calcium (Ca), magnesium (Mg) and sulphur (S). Micro- or also called as trace nutrients are required in very small amounts compared to primary or secondary nutrients. Micronutrients are zinc (Zn), iron (Fe), copper (Cu), manganese (Mn), molybdenum (Mo), boron (B), chlorine (Cl) and nickel (Ni).

Soil tests are quite useful in assessing nutrients needs and sources. A typical soil chemical analysis for potatoes should include pH, EC, organic matter, N, P, K,

Ca, Mg, S, Zn, Fe, Cu, Mn, Mo and B. Physical parameters like soil texture and water holding capacity are important for water management. For most accurate fertilizer recommendations, soil test results should be interpreted based on regional research. Tissue tests (leaf and petiole), if performed timely, are useful in correcting in-season deficiencies. Tissue analysis has been used for many years as an additional nutrient management tool to help predict the need for additional nutrients, diagnosis of nutrient deficiency or toxicity, and to monitor the effectiveness of a fertilizer programme. If the level of nutrient in tissues falls outside the prescribed optimum range on lower side then corrective measures should be taken.

Nitrogen (N): Amongst essential elements, nitrogen is often the one most yield limiting nutrient for potato growth. Application of fertilizer N is usually necessary to ensure profitable potato production. Both N rate and timing can have important impacts on yield and

quality. Early stage application of N is essential to ensure early row closure (canopy development). However, excess of N delays tuber initiation and maturity leading to excessive vine growth at the expense of tuber growth and delayed maturity results in tubers with lower specific gravity. Nitrogen uptake by the potato plant is highest during the tuber bulking stage. While deciding on N needs, fertilizer value of the manures applied to previous crops as well as present crops should be taken into consideration. Factors like variety, yield potential or goal, growing season, soil organic matter content, and previous crop should also be considered while deciding on the rate of N application. Kufri Pukhraj is more responsive to N compared to Kufri Jyoti. Nitrogen application rates vary considerably from 120 -150 kg N/ha in hills to 180-240 kg N/ha in plains depending on soil and variety and target yield. Nitrogen deficiency can increase the early blight infestations. Use of chlorophyll meters for checking N status of plants can help in minimizing seasonal variations in N availability. Experiments conducted at different locations have indicated a saving of 10-20% compared to blanket application. Split applications of N are recommended for potatoes from both a production and an environmental safety point. Nitrogenous fertilizers like urea should be incorporated into the soil immediately after their application



Fig. 1. Nitrogen deficiency leads to poor canopy and chlorophyll (LHS) in potato

or applied as fertigation to avoid volatilization losses. Under drip irrigation, it is recommended to apply one third ($1/3^{\text{rd}}$) N as basal application and remaining two third ($2/3^{\text{rd}}$) in 8 splits depending upon crop duration as fertigation twice a week up to 50 days after planting starting from emergence. Drip fertigation can save 25% N fertilizer in comparison to furrow method of irrigation.

In soils having low nitrogen, a portion of the N (50% to two third) should be applied preplant or planting and the remainder at earthing up stage. Common N sources include urea, calcium ammonium nitrate and ammonium sulphate etc. Choice of fertilizer sources depends on cost as

well as need for other nutrients also. Fertilizers like ammonium sulphate will supply both nitrogen and sulphur. Similarly, calcium ammonium nitrate and calcium nitrate will supply calcium apart from N. Urea is cheaper than above mentioned fertilizers. Ammonium sulphate provides greater acidifying effect, and hence in high pH soils or soils which need both N and S, use of ammonium sulfate is preferred. Phosphatic fertilizers like ammoniated phosphorus e. g. DAP contains 18% N and 46% P_2O_5 and urea phosphate adds significant quantities of N. These facts should be taken into account while deciding the N dose through other fertilizer sources. Care should be taken not to apply high amounts of ammonium containing fertilizer in bands close to the seed as it may cause ammonia toxicity especially in high pH soils. Nitrate sources of N are susceptible to leaching hence they are preferably applied in splits or via irrigation water (fertigation). To minimize nitrogen volatilization losses, urea also needs to be incorporated into the soil or applied with irrigation water (fertigation) otherwise there are chances of N loss due to ammonia volatilization.

Phosphorus (P): Adequate availability of P is important for early crop development (Fig. 2), tuber initiation and tuber maturity. Phosphorus deficiency significantly reduces tuber yield size as well as



Fig. 2. Crop growth reduced by P deficiency (LHS) in potato crop

specific gravity. Its demand is high in the initial growth period, hence basal application of P fertilizers is recommended. A healthy potato crop removes about 25-30 kg P_2O_5 /ha. Potato being shallow rooted crop, P-use efficiency is hardly 10-15% in conventional method of soil application. Hence heavy doses of P fertilizers are needed. However, in soils having high available P (Olsen's $P > 20$ ppm), invariably no response has been observed in alluvial soils. In soils having low P, 100-150 kg P_2O_5 is recommended at the time of planting as band placement. This increases early-season availability as P concentration is sufficient in a narrow zone near the seed piece. DAP i.e. Diammonium phosphate (46% P_2O_5 , 18% N) in neutral to alkaline soils and superphosphate (16% P_2O_5 , about 20% calcium) for acidic soils are most commonly used phosphatic fertilizers. In acidic soils of north eastern India and Nilgiri hills, rock phosphate in combination with phosphorus solubilizing microbes can be used. Use of 30 tonnes FYM will reduce the phosphorus need by 50%. To avoid P-fixation and to get economic results, high levels of organic carbon must be maintained in soil. Foliar application of P can provide temporary relief from deficiencies but cannot substitute soil application. Sprinkler application of P fertilizer is effective for correcting in-season potato P deficiencies provided active roots are near the soil surface as P hardly moves below two inches in soil.

Potassium (K): Potassium plays important roles in tuber yield and quality. Potassium is associated with a number of tuber quality factors including specific gravity, blackspot bruise susceptibility, chip and fry colour, and storage quality. Potassium deficiencies is associated with decreased photosynthesis, reduced dry matter and starch formation, and an increased incidence of internal black spot bruising. A healthy crop of potatoes removes on average 4.60 kg K_2O per tonnes of tuber yield corresponding to about 170-230 kg

K_2O /ha depending upon the variety, crop duration and agro-climatic region. Maximum accumulation of K takes place between 30 to 60 days of planting in the plains and between 65 to 85 days in the hills. Therefore, a ready supply of K from the soil is required during the early stages of growth of the fast growing potato crop. The uptake efficiency of potassium fertilizers is 50-60% thus considerable residual effects are observed in the succeeding crops unless substantial leaching does not take place in sandy soils. Soils, tests have been found to be very useful in predicting response to K fertilizers. On low K testing soils, about 100-150 kg K_2O /ha is applied as basal dose depending on the soil type. Potassium chloride (0-0-60) also known as MOP is the most economical K source. However due to its high salt index, it may increase salinity problems under saline irrigation. Other important fertilizer sources are potassium sulphate (SOP) and potassium nitrate. For processing potatoes, potassium sulphate is preferred over MOP. Split applications of potassium can be done in very sandy or heavy textured soils. In-season applications of K fertilizer tend to increase bulking, but will usually lower specific gravity.

Calcium (Ca), magnesium (Mg) and sulphur (S): In general, most Indian soils contain sufficient amounts of secondary nutrients for potato production or these are present in one or the other commonly used fertilizer sources except magnesium. However, acid and very sandy soils having low organic matter may require addition of one or more of these nutrients. Calcium plays an important role in maintaining tuber quality in storage and reducing internal tuber disorders due to water or temperature stress. Water or temperature stress may cause inadequate transport of Ca in the tubers despite high calcium in soils. Calcium nitrate and single superphosphate (as a source of Ca) can be used to increase tuber calcium concentrations.

Magnesium is central to

chlorophyll molecule and its deficiency reduces chlorophyll and hence reduces the yield drastically. Magnesium deficiency can be a problem in soils where high rates of potassium fertilizers have been applied. Response is likely if soil test Mg is less than 50 ppm. Sulphur requirements can often be met from soil organic matter breakdown and irrigation water also contain some sulphate and can provide a significant proportion of the sulphur needed for growth. Ammonium sulphate and potassium sulphate when used as N and K sources, respectively, will supply sufficient sulphur when a need is indicated from soil or tissue tests. Sulphur from elemental sulphur is not available immediately and must be oxidized by soil bacteria to sulphate before it can be used by the plants. Hence it should be applied along with FYM.

Micronutrient management:

Zinc (Zn), boron (B), copper (Cu), manganese (Mn), nickel (Ni), iron (Fe), chlorine (Cl) and molybdenum (Mo) are micronutrients. As mentioned earlier, micronutrients are needed in much lower quantities; however, they are equally important as macronutrients. Micronutrients' deficiency can cause serious reduction in yields. Application of micronutrients is recommended only if a need is indicated by soil and/or tissue. In general, most soils contain sufficient amounts of micronutrients to meet plant needs and if farm yard manure is applied regularly, it will supply most of the micronutrients demand. Boron may be limiting in sandy soils and excessive B applications can be toxic. Boron reduces the incidence of tuber discolouration by reducing the oxidation of phenols that are responsible for enzymatic discolouration. Foliar application is most effective way to correct in-season micronutrient deficiencies. Foliar spray during dry spell should be avoided during 11 AM and 3 PM to avoid scorching of leaves. Recommended doses to correct the micronutrient deficiency are given in Table 2.

Table 2. Micronutrients doses for correction of deficiencies

Micronutrient	Fertilizer source	Soil application (kg/ha)	Spray application (g/100 litre water)	Tuber soaking (g/100 litre water)
Zinc	Zinc sulphate	25	200	50
Iron	Ferrous sulphate	50	300	75
Copper	Copper sulphate	25	200	50
Manganese	Manganese sulphate	25	200	50
Molybdenum	Ammonium molybdate	2	100	20
Boron	Sodium borate	2	100	20

Irrigation management

Irrigation is vital for potato production to maximize both yield and quality. Potato is mainly grown in light textured soils and it requires light and frequent irrigation throughout the crop growth period to obtain optimum crop yield. In India, it is grown both as rainfed as well as irrigated crop depending on the season and the region. The crop is sensitive to moisture stress and most of the studies have indicated stolon initiation followed by tuberization as the most critical stages for potato. Depletion of more than 50% of total available soil moisture during this period results in considerable yield loss. Depending on the severity of water stress, various tuber shape distortions are also observed.

On an average, the irrigation water requirement of the crop, under conventional system, varies from 300-600 mm under Indian conditions depending upon soil type/texture, climate, variety and length of growing period, rainfall pattern and other management practices. The crop productivity and quality of the tubers largely depend upon proper balance between soil air and soil water in the plant root zone. Both low as well as excess water in soil during crop growth stages affect the crop performance. However, impact of excess or low soil moisture varies with the crop growth stage. Excess soil moisture creates aeration problem and favours certain diseases and pests. The general practice of overirrigating the crop leads to excess residual moisture in soil profile. This coupled with the risk of heavy rainfall at the fag end of the crop season in Indian plains often increase the post-harvest rottag losses.

Irrigation scheduling: The purpose of irrigation scheduling is to obtain best results by applying the just required quantity of water. This depends largely on the prevailing weather situation and crop growth stage. Potato crop is highly sensitive to moisture stress. Even mild stress at critical stages can cause significant yield loss. The purpose of irrigation management is to maximize potato yield and quality by maintaining soil water content within optimum limits throughout the crop growing season. Hence proper irrigation scheduling is must to obtain best results by applying the required quantity of water depending on the crop phase and prevailing weather situation particularly during critical stages. Stolon formation, tuber initiation and tuber development stages are critical for achieving higher yield. As a thumb rule, the available soil moisture (ASM) in the root zone should be maintained between 65 and 85% (v/v) during the active crop growth period. To ensure uniform germination, one light irrigation before or after planting should be applied, if necessary. The commonly used methods to schedule irrigation involve i)

atmospheric measurements and water balance technique; ii) soil moisture monitoring and iii) plant stress measurements. Soil moisture monitoring by using soil moisture measuring devices like tensiometers and use of cumulative pan evaporation are most common approaches for irrigation scheduling.

Since potato crop requires light and frequent irrigations, this can be achieved best by micro-irrigation systems like drip or sprinkler through timely and controlled water discharge. Because of recurring droughts in many parts of the country and declining water table in many areas of north-western and central plains of India due the overdraft of ground water i.e. at rates higher than recharge, more and more emphasis is being given on installing micro-irrigation system particularly drip system, a proven water-conserving irrigation technique. In conventional furrow irrigation method, nutrient use efficiencies are low, 30-50% for N, 10-20% for P and 40-50% for K. In contrast, micro irrigation increases both nutrient and water-use efficiency (Table 3) largely due to split applications and proper balance of soil air and soil water and optimum hydrothermal regime in the plant's root zone. These conditions facilitate better root growth, uniform and sustained tuber development, thus ensuring higher yield of quality tubers.

Sprinkler irrigation: This system gives uniform distribution and is expected to economize on water by about 40% since water application can be regulated as per



Fig. 3. Potato crop under drip irrigation

the infiltration rate of the soil and there is an overall reduction in deep percolation losses. The studies based on sprinkler irrigation approach, revealed that irrigations at 150% cumulative pan evaporation (CPE) rate twice a week are needed for best yield of potato.

Drip irrigation: Drip irrigation is growing as a preferred irrigation method as it can provide better production and water-use efficiency. Compared to furrow irrigation, drip method requires about 50% less

water. Drip irrigation compared to sprinkler is advantageous in areas having saline water, as it delivers the water below the level of the crop canopy, thereby avoiding damage to foliage by salts. It is recommended to apply irrigation using drip on alternate days at the rate of 125% of CPE (cumulative pan evaporation) for best results. The irrigation interval of more than three days may lead to moisture stress. Drip fertigation could save about 25% NPK dose compared to furrow irrigation.

Table 3. Benefits of micro-irrigation over furrow irrigation

Component	Sprinkler irrigation	Drip irrigation
Water savings	30-40%	40-50%
Crop productivity	15- 20% increase	25-35% increase
Fertilizer economy	25% N	25% NPK
Labour savings	20-25%	30-35%

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