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Effect of Moisture Regime and Customized Fertilizer on Water Use Efficiency and Economics of Potato (*Solanum tuberosum* L.)

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A B S T R A C T

A field experiment was conducted to study the "Effect of moisture regimes and customized fertilizers on the performance of potato (*Solanum tuberosum* L.)" during *Rabi* season of 2010-11 at Agronomy Research Farm, Narendra Deva University of Agriculture & Technology (Narendra Nagar), Kumarganj, Faizabad. Highest WUE efficiency was recorded with 6 cm irrigation at 1.0 IW/CPE ratio and customized fertilizer (F_4). The highest net return and benefit-cost ratio of Rs. 79309.00 ha^{-1} and 1.78 were computed under treatment combination I_2 F_4 (6 cm irrigation at 1.0 IW/CPE ratio + 8 : 18 : 26 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 67.5 : 97.5 : 3.75 : 0.37 : 22.5 kg ha^{-1}).

Introduction

Potato (*Solanum tuberosum* L.) ranks fourth among major food crops of the world, occupying an area of 19.26 million ha with annual production and productivity of 320.71 million tonnes and 16.64 tonnes/ha, respectively (http:// www.fao.org). Asia and Europe are the world's major potato producing regions, accounting for more than 80 per cent of world production. Irrigation and fertilization are two important inputs in potato production and increased production depends upon efficient use of irrigation water and fertilizers throughout the growth period. In the present day context, the effective and economic utilization of water and fertilizers is very essential to reduce the cost of cultivation and can best be achieved through the use of improved irrigation techniques, viz. drip, sprinkler and supplying balanced and adequate doses of fertilizers. Use of drip and sprinkler irrigation can increase the yield up to 20–40 % along with water saving up to 39 % in potato crop (Pawar *et al*., 2002). However, their adoption is restricted mainly due to huge investment needed for installation during the initial period. Therefore, the economic feasibility of these techniques is needed to be assessed for a short-duration crop like potato. The response of applied fertilizers is also expected to vary with different methods of irrigation as frequency of water application is different in sprinkler, drip and conventional furrow irrigation system. Further, it has been reported that soil temperature causes large fluctuations in potato yield and can be manipulated to some degree by adjusting the soil moisture. High evaporation rate and low amount of rainfall

during that period reduced the moisture from the soil surface and creates a drought like situation which reduced the yield. Potato is very sensitive to water stress and even short term water stress can cause significant reduction in yield. Therefore, irrigation based on cumulative pan evaporation will help to maintain the soil moisture without any waste of water. Keeping this in view the present study was made to find the best irrigation schedule Therefore, the present studies were conducted to evaluate variable fertilizer doses under different irrigation methods and assess the economic feasibility of these techniques.

Nutrient management being one of the most important input with sufficient available water to achieve potential yield of potato. Water is an important input for potato production and its management problem varies from irrigation to irrigation. Optimum soil moisture is needed to be maintained in root zone to meet crop requirement for higher yield. It can be achieved best through the use of drip and sprinkler irrigation system. However its adoption is restricted mainly due to high investment for short duration crop like potato, which is most sensitive to soil moisture and irrigated by underground water and which is day by day the depleting. Hence economization of water is a need of the hour.

Beside irrigation other factor is being fertility levels and among different plant nutrients nitrogen, phosphorus and potassium being most important elements for promoting growth, yield and quality of tubers in potato. Nitrogen is an essential constituent of protein and chlorophyll and found physiological importance in plant metabolism such as nucleotides, phospholipids, alkaloids, enzymes hormones and vitamin. Nitrogen promotes vegetative growth, tuber number and tuber size. It increases to considerable extent the utilization of potassium, phosphorus and other micro nutrients. Sulphur is constituent of essential amino acid, vitamin and aromatic compound and provides resistance against insect, pest and disease resistance in plants.

The phosphorus is second limiting, nutrient in potato production. Its deficiency retards the growth and leaves become dull without luster and increase tuber yield and number of medium size tuber.

Potassium is the next essential nutrient for potato production. The requirements of potato crop for potassium or higher than those of cereals. It increases the tuber yield by increasing the number of large size tuber. Micro nutrients in balanced proportion increase potato yield by retards deficiency symptoms. Potato tuber yield increased significantly by application of zinc sulphate (Neelima Joshi & Raghav, 2005).

Besides major nutrients boron and zinc are the most important micro nutrient particularly in our country because most of Indian soils are deficient in these nutrients. Boron is essential for translocation of sugar, reproduction for IAA and other metabolic processes. Zinc is essential mineral for IAA synthesis. Zinc deficiency is closely related to the inhibition of RNA synthesis, reduces root and shoot growth and chlorophyll concentration of leaves. Zinc is directly or indirectly required by the several enzyme systems and closely involved in the nitrogen metabolism of plant.

The costs of chemical fertilizers have enormously gone up and are still on increase it is necessary to examine alternative, cheaper and easily available nutrient source to meet out fertilizer requirements.

Materials and Methods

The experiment was conducted during the winter season 2010-11 at Agronomy Research Farm, Narendra Deva University of Agriculture & Technology, Kumarganj,

Faizabad (U.P.). The soil of experimental field was silt loam in texture, alkaline (pH 8.0), poor in organic carbon (0.35%) and deficient in available N (147.5 kg/ha), medium P (14.50 kg/ha) and rich K (210.1 kg/ha). The treatments *viz.* two moisture regime- 0.8 IW/CPE ratio, 1.0 IW/CPE ratio with 6 cm irrigation water depth and six customized fertilizers *viz*. ICAR application F_1 (N:P:K:Zn:B:S) 120 : 80 : 100 : 2 : 0 : 8, F_2-12 : 26 : 18 : 1 : 0 : 6 (N:P:K:Zn:B:S 150 : 97.5 : 67.5 : 3.75 : 0 : 22.5 kg ha^{-1}), F_3-18 : 28 : 10 : 1 : 0 : 6 (N:P:K:Zn:B:S 150 : 105 : 37.5 : 3.75 : 0 : 22.5 kg ha^{-1}), F_4-8 : 18 : 26 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 67.5 : 97.5 : 3.75 : 0.37 : 22.5 kg ha^{-1}), F_5- 8 : 14 : 24 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 52.5 : 90: 3.75 : 0.37 : 22.5 kg ha^{-1}) and F_6-8 : 12 : 28 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 45 : 105: 3.75 : 0.37 : 22.5 kg ha^{-1}). The experiment was laid out in Randomized Block Design with four replications.

All the nutrients except N were applied basal as per treatment except N. Nitrogen was applied in 2 splits between sowing and first and second irrigation. Sulphur, zinc and boron were applied as elemental sulphur (85 % S), zinc chloride (45 % Zn) and borax (11 % B) respectively. Potato variety, 'Kufri Ashoka' was sown at spacing of 50 cm × 20 cm on 9th November in 2010-11. Weed growth was controlled by hand-weeding. All the other recommended package of practices were adopted during the crop-growth period. The crop was harvested in the first week of February, and tuber yield was recorded. After taking into consideration the variable and fixed inputs, the expenditure incurred on various inputs was worked out for each treatment. The selling price of potato was Rs. 4000/ tonnes and gross returns were calculated on the basis of this price. Benefit-cost ratio was worked out for different treatments. At the end of the experiment, total amount of water applied was calculated for each irrigation treatment and the water use efficiency (tonnes ha^{-1} cm) was calculated as per the formula:

Water-use efficiency = Total yield of tubers (tonnes) / Total water applied (cm)

Result and Discussion

Water use efficiency

The consumptive use of water (CU) and water use efficiency (WUE) increasing with increasing nutrient proportion up to customize fertilizer F_4-8 : 18 : 26 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 67.5 : 97.5 : 3.75 : 0.37 : 22.5 kg ha^{-1}) (Table-2) Application of more nitrogen favored the growth of plants, as they consumed more amount of water for their metabolic processes and transpiration which in term led to higher consumptive use. The increase in water use efficiency with increasing nutrient level was mainly due to proportionately higher increase in tuber yield than consumption of water.

Starch content of the tuber is also affected by moisture regimes. Increasing the regimes decreased the starch content in the tuber. This reduction in starch is due to hydrolysis of starch in to sugar at higher water supply. Moreover, larger supply of moisture has increased the water content of the tuber. Pahuja and Sharma (1982) also reported similar results.

Tuber yield per unit of water applied increased significantly in case of lower moisture regime than higher regimes. I_2 moisture regime has significantly lower value of tuber yield per unit of water applied in comparison to I_1 ratio (Table-1 & 2.). Under I_2 moisture regime value decreased due to fact that the water applied at this moisture regime was more than its lower level but the tuber yield differences was not so wide, the result in close conformity with the findings of Bhan and Dhama (1982), Hane and Pumphrey (1984) and Chandra *et al.*, (2001).

Table.1 Total tuber weight (kg plot^{-1}) and (q ha^{-1}) as influenced by moisture regimes and customized fertilizers

Treatments	Total tuber weight (kg plot^{-1})	Total tuber yield (q ha^{-1})
Moisture regimes		
I_1	26.42	220.19
I_2	27.84	232.03
SEm±	0.28	2.39
CD at 5%	**0.82**	**6.90**
Customized fertilizers		
F_1	23.44	195.36
F_2	26.81	223.44
F_3	25.30	210.83
F_4	30.32	252.66
F_5	27.71	230.89
F_6	29.22	243.49
SEm±	0.49	4.14
CD at 5 %	**1.43**	**11.96**

Table.2 Total water received and water use efficiency as influenced by moisture regimes and customized fertilizers

Treatments	Total water received (cm)	Water use efficiency (kg ha^{-1} cm^{-1})
Moisture regimes		
I_1	16.3	135.0
I_2	22.3	104.04
Customized fertilizers		
F_1	19.3	101.22
F_2	19.3	115.77
F_3	19.3	109.23
F_4	19.3	130.91
F_5	19.3	119.63
F_6	19.3	126.16

Table.3 Economics of different treatment combinations

Treatments	Gross return (Rs. ha^{-1})	Total cost of cultivation (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C
I_1F_1Irrigation at 0.8 IW/CPE ratio + ICAR application N:P:K:Zn:B:S 120 : 80 : 100 : 2 : 0 : 8	90760	43468	47292	1.08
I_1 F_2 Irrigation at 0.8 IW/CPE ratio + customize fertilizer -12 : 26 : 18 : 1 : 0 : 6 (N:P:K:Zn:B:S 150 : 97.5 : 67.5 : 3.75 : 0 : 22.5 kg ha^{-1})	104000	43741	60259	1.37
I_1 F_3 Irrigation at 0.8 IW/CPE ratio + customize fertilizer- 18 : 28 : 10 : 1 : 0 : 6 (N:P:K:Zn:B:S 150 : 105 : 37.5 : 3.75 : 0 : 22.5 kg ha^{-1})	99040	43589	55451	1.27
I_1 F_4 Irrigation at 0.8 IW/CPE ratio + customize fertilizer -8 : 18 : 26 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 67.5 : 97.5 : 3.75 : 0.37 : 22.5 kg ha^{-1})	118840	43841	74999	1.71
I_1 F_5 Irrigation at 0.8 IW/CPE ratio + customize fertilizer- 8 : 14 : 24 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 52.5 : 90: 3.75 : 0.37 : 22.5 kg ha^{-1})	108360	43502	64858	1.49
I_1 F_6 Irrigation at 0.8 IW/CPE ratio + customize fertilizer -8 : 12 : 28 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 45 : 105: 3.75 : 0.37 : 22.5 kg ha^{-1})	113320	43510	69810	1.60
I_2 F_1 Irrigation at 1.0 IW/CPE ratio + ICAR application N:P:K:Zn:B:S 120 : 80 : 100 : 2 : 0 : 8)	96800	44118	52682	1.19
I_2 F_2 Irrigation at 1.0 IW/CPE ratio + customize fertilizer -12 : 26 : 18 : 1 : 0 : 6 (N:P:K:Zn:B:S 150 : 97.5 : 67.5 : 3.75 : 0 : 22.5 kg ha^{-1})	110600	44391	66209	1.49
I_2 F_3 Irrigation at 1.0 IW/CPE ratio + customize fertilizer 18 : 28 : 10 : 1 : 0 : 6 (N:P:K:Zn:B:S 150 : 105 : 37.5 : 3.75 : 0 : 22.5 kg ha^{-1})	103400	44539	59161	1.32
I_2 F_4 Irrigation at 1.0 IW/CPE ratio + customize fertilizer -8 : 18 : 26 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 67.5 : 97.5 : 3.75 : 0.37 : 22.5 kg ha^{-1})	123800	44491	79309	1.78
I_2 F_5 Irrigation at 1.0 IW/CPE ratio + customize fertilizer - 8 : 14 : 24 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 52.5 : 90: 3.75 : 0.37 : 22.5 kg ha^{-1})	113320	44152	69168	1.56
I_2 F_6 Irrigation at 1.0 IW/CPE ratio + customize fertilizer -8 : 12 : 28 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 45 : 105: 3.75 : 0.37 : 22.5 kg ha^{-1})	120440	44160	76280	1.72

Economics

The variation in cost of cultivation were recorded due to moisture regime, customized fertilizers, which was increased with increasing level of nutrient in customized fertilizers, irrigation are the major monitory inputs. Yield was major factor, which caused differences in net income and net return per rupee invested (Table-3).

Maximum cost of cultivation was recorded under the moisture regime of 1.0 IW/CPE ratio + customize fertilizer F_3-18 : 28 : 10 : 1 : 0 : 6 (N:P:K:Zn:B:S 150 : 105 : 37.5 : 3.75 : 0 : 22.5 kg ha^{-1}) while minimum under treatment combination of 0.8 IW/CPE + customize fertilizer ICAR application N:P:K:Zn:B:S 120 : 80 : 100 : 2 : 0 : 8. Maximum gross return (Rs. 123800 ha^{-1}) was

recorded under the treatment combination of 1.0 IW/CPE ratio + customized fertilizers F_4-8 : 18 : 26 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 67.5 : 97.5 : 3.75 : 0.37 : 22.5 kg ha^{-1}). The cost of cultivation was more due to more number of irrigations, higher dose of nutrient which increased cost of irrigation. Gross return was more due to higher production of tubers (Table-1&3).

Highest net return were obtained under 1.0 IW/CPE ratio + customized fertilizers F_4-8 : 18 : 26 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 67.5 : 97.5 : 3.75 : 0.37 : 22.5 kg ha^{-1}) and highest benefit : cost ratio (1.78) were also recorded under the treatment combination of I_2F_4 1.0 IW/CPE ratio + customized fertilizers F_4-8 : 18 : 26 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 67.5 : 97.5 : 3.75 : 0.37 : 22.5 kg ha^{-1}). This was found due to low cost of irrigation and customized fertilizers (Table-3).

In conclusion every increase in the level of moisture regime increase in consumptive use of water and decrease water use efficiency. The higher water use efficiency (135.0) was recorded under 0.8 IW/CPE ratio which was more than that obtained under I_2.

Minimum cost of cultivation was incurred under I_1 moisture regime but maximum gross income was calculated under I_2. Maximum net return and net profit per rupees was also recorded under I_2. Minimum cost of cultivation was incurred under customized fertilizer F_3-18 : 28 : 10 : 1 : 0 : 6 (N:P:K:Zn:B:S 150 : 105 : 37.5 : 3.75 : 0 : 22.5 kg ha^{-1}) but maximum gross income, net return and benefit cost ratio were computed under F_4 -8 : 18 : 26 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 67.5 : 97.5 : 3.75 : 0.37 : 22.5 kg ha^{-1}) followed by F_6-8 : 12 : 28 : 1 : 0.1 : 6 (N:P:K:Zn:B:S 150 : 45 : 105: 3.75 : 0.37 : 22.5 kg ha^{-1})

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