

Evaluation of different fertilizer types in potato crop under various irrigation regimes

B.S. Sekhon* and C.B. Singh

Department of Soil Science, Punjab Agricultural University, Ludhiana-141004. *E-mail: bsekhon@pau.edu

Abstract

India is the second largest producer of potatoes in the world. Shallow root system makes potato crop an inefficient nutrient consumer and sensitive to water stress. Anecdotal evidence hints that many potato growers of northwest India prefer complex NPK fertilizers or compound NP fertilizers over the straight fertilizers because they believe the former to be more efficient on agronomic basis. Thus, this study was aimed at conducting a comparative evaluation of various fertilizer sources across different irrigation and FYM regimes over two years on a loamy sand soil. A field experiment in split-split plot design was used with one additional blocking factor of soil variability. The main plot involved two FYM levels (0 and 50 t ha⁻¹) and three irrigation water pan evaporation (IWPE) based irrigation regimes (IR₁ with IWPE 2.0, IR₂ with IWPE 1.4, and IR₃ with IWPE 0.8) in sub-plots. Four fertilizer treatments in sub-sub plot involved a check (T0); T1 with N,P, and K respectively from straight fertilizers urea, single superphosphate (SSP), muriate of potash (MOP); T2 with P from DAP, remaining N from urea, and K from MOP; T3 with P from NPK complex (12:32:16) fertilizer and the remaining N from urea and K from MOP. General trends in tuber yield and irrigation water use efficiency (IWUE) during the year 2011 and statistically proven results of various *a priori* single degree of freedom contrasts showed that NPK complex fertilizer and NP compound fertilizer performed better than straight fertilizers.

Key words: Potato, India, complex fertilizer, farmyard manure, irrigation, contrasts.

Introduction

Potato (*Solanum tuberosum* L.) is one of the most important crops world over owing to its substantial use in human food and starch industry (Fabeiro *et al.*, 2001). Potato crop with 1.91 million hectare area is the largest grown vegetable crop in India. It occupies around 29% of the gross cropped area under vegetable crops in the country (Govt. of India, 2013). India with 11% share in global potato production is the second largest producer of potatoes in the world. Majority (>80%) of the potato production results from the highly fertile alluvial soils spreading from Punjab in the northwest to West Bengal in the northeast (Gupta *et al.*, 2007). Potato crop is characterized by a shallow root system which makes it an inefficient nutrient consumer. Thus, due to great dependence of yield on nutrient availability, research on appropriate nitrogen (N), phosphorus (P), and potassium (K) fertilizer regimes has received considerable attention worldwide (Kulhanek *et al.*, 2008; Vos, 2009). The shallow root system also makes this crop highly sensitive to water stress (Porter *et al.*, 1999). Irrigation regimes impact nutrient use efficiency as well (Li *et al.*, 2011; Ezzat *et al.*, 2011). The dependence of yield on nutrient supply has also promoted use of farmyard manure (FYM) in this crop in India (Roy *et al.*, 2006).

Anecdotal evidence suggests that many farmers in the potato growing regions of northwest India prefer the use of complex NPK fertilizers or compound NP fertilizers over the straight fertilizers because they believe the former to be more efficient on agronomic basis. Viewing this, the study was undertaken with the objective of conducting a comparative evaluation of various fertilizer sources across different irrigation and FYM regimes.

Materials and methods

A field experiment was conducted at Soil Science Research Farm of Punjab Agricultural University Ludhiana for two years (year 2011-12 and 2012-13) on a loamy sand soil. Keeping in view the highly heterogeneous fertility status of the field at the start of the experiment during the year 2011, the field was divided into three equal blocks. The blocks were cut across in two halves. To one part no FYM (FYM₀) was applied whereas to the other part FYM was applied @ 50 t/ha (FYM₅₀). The FYM was applied just before planting and after the preparatory tillage. Each level of FYM had three randomized irrigation regimes IR₁, IR₂, and IR₃. In IR₁ regime, the irrigation was scheduled on the basis of irrigation water to pan evaporation (IWPE) ratio of 2.0. Likewise, the IR₂ regime involved an IWPE of 1.4 and the IR₃ scheduled irrigation on the basis of IWPE ratio of 0.8. After factoring in the initial uniform irrigation after planting across all regimes, the total water use came out to be 25 cm in IR₁, 20 cm in IR₂, and 15 cm in IR₃. Three fertilizer treatments (T1, T2, and T3) in addition to one check (T0) that involved raising the crop without using any fertilizer were further randomized under each irrigation regime. The T1 treatment involved sourcing the N, P, and K respectively from straight fertilizers urea, single superphosphate (SSP, 16% (g) P₂O₅), and muriate of potash (MOP, 60% K₂O). The T2 treatment consisted of sourcing P from diammonium phosphate (DAP, 18:46) and the remaining N requirement from urea. The K requirement under this treatment was met from MOP. The T3 treatment involved meeting P requirement from NPK complex (12:32:16) fertilizer and the remaining N and K requirement respectively from urea and MOP. The incidental S input from the SSP (sulphur content 11%) was balanced by using gypsum in other treatments. The fertilizer N, P, and K levels (190 kg/

ha N, 60kg/ha P₂O₅, and 60kg/ha K₂O) were uniform across all the three fertilizer treatments and were in accordance with the general recommendations (by the Agricultural University of the region) for the potato crop in the region. Each factor combination had three replicates (total 72 plots). The plots were planted to healthy potato (var. *Kufri Chandermukhi*) tubers during the first fortnight of October each year on beds spaced 60 cm apart. The tuber to tuber distance was 20 cm. Half of the N fertilizer and the whole of P and K fertilizers were drilled at the time of planting. The remaining half of the N fertilizer was applied at the time of earthing up after about four weeks. The weed control was effected through the pre-emergence and after first irrigation application of pendimethalin 30% EC. The crop was hoed subsequently as per need. The furrow method was used for irrigation and the first irrigation was uniformly applied across all the treatments immediately after planting. The remaining irrigations were scheduled on the basis of the various aforementioned irrigation water-pan evaporation ratios. The harvesting was done by digging out tubers manually. Tuber yields and the amount of irrigation water used were recorded.

The data for the two years were not pooled for analysis as they did not pass the homogeneity of variance test. The results from each year were subjected to PROC GLM method of Statistical Analysis System (SAS 9.3). The statistical analysis was primarily aimed at examining a host of *a priori* single degree of freedom contrasts in accordance with the objectives of the study. These contrasts are detailed in Table 3.

Results and discussion

The effect of FYM and irrigation water regimes on fresh tuber yield followed the same pattern during the two years (Tables 1 and 2). During the year 2011, the FYM caused a mean increase of about 24% whereas during the year 2012, the increase (54%) was much higher. The contrast between the two years can be ascribed to the highly heterogeneous soil fertility status of the experimental field at the start of the experiment during the year

2011. The gradual removal of water stress helped increase the yields. During the first year, across all FYM levels, the IR₂ irrigation regime increased tuber yield by about 14% over the most stressed IR₃ regime. The corresponding increase with IR₁ was about 29%. However, the effect was more conspicuous in the absence of FYM where the corresponding increments over the most stressed IR₃ regime were 21 and 51%. The FYM use confounded the favorable effect of increasing water availability. During the second year, however, the effects became less intense. Across all FYM levels, the IR₂ regime increased the yield over the IR₃ regime by 5% and the IR₁ increased it by 13%. In the absence of FYM, the corresponding changes were 12 and 22%, respectively.

During the first year of the experiment, the T3 treatment that involved the use of NPK complex 12:32:16 fertilizer outperformed the other fertilizer treatments T1 and T2 across all irrigation schedules, in the absence of FYM. In the presence of FYM, T1 treatment performed best. However, T3 remained better than T2. During the following year, however, T3 treatment maintained its supremacy even in the presence of FYM.

Investigations into the irrigation water use efficiency trends showed that it followed the pattern of yield response. During the first year, the highest IWUE in the absence of FYM was associated with T3 treatment and in the presence of FYM, higher IWUE values were recorded with straight fertilizer sources (T1). Likewise, during the second year higher IWUE was demonstrated by the T3 treatment. This was irrespective of the FYM amendment level.

In order to address the main objective of the experiment, a host of single degree of freedom contrasts between various treatments under different irrigation and FYM use scenarios were studied. The results with respect to tuber yield are shown in Table 3 and of IWUE in Table 4. Contrasts for the year 2011 did not reveal much information as compared to those for the year 2012. This possibly happened due to highly heterogeneous fertility environment of the

Table 1. Potato tuber yield under various FYM levels (0 and 50 t ha⁻¹), irrigation regimes, and fertilizer sources during the year 2011

Irrigation Regime	Tuber yield (q ha ⁻¹)									
	FYM ₀					FYM ₅₀				
	T0	T1	T2	T3	Mean	T0	T1	T2	T3	Mean
IR ₁	79.6	162.4	147.4	166.0	138.9	101.8	169.7	160.1	163.7	148.8
IR ₂	64.7	118.1	121.2	139.0	110.8	85.3	177.9	151.9	156.1	142.8
IR ₃	63.8	97.8	103.5	102.1	91.8	93.3	145.0	139.2	145.3	130.7
Mean	69.4	126.1	124.0	135.7	113.8	93.5	164.2	150.4	155.0	140.8
Significance level	Block: ** FYM: *** IR: ** Treatment: ** Block*FYM: NS, FYM*IR: NS ^b , Block*FYM*IR: *, Treatment*FYM: NS, Treatment*IR: NS, Treatment*FYM*IR: NS									
LSD (P=0.05)	Block:8.7, FYM: 7.1, IR:8.7, Treatment:10.0									

Irrigation Regime	IWUE (q tuber ha ⁻¹ cm ⁻¹)									
	FYM ₀					FYM ₅₀				
	T0	T1	T2	T3	Mean	T0	T1	T2	T3	Mean
IR ₁	3.98	8.12	7.37	8.30	6.94	5.09	8.49	8.00	8.19	7.44
IR ₂	3.24	5.90	6.06	6.95	5.54	4.26	8.90	7.60	7.81	7.14
IR ₃	4.25	6.52	6.90	6.81	6.12	6.22	9.67	9.28	9.68	8.71
Mean	3.82	6.85	6.78	7.35	6.20	5.19	9.02	8.29	8.56	7.77

Significance level Block: ** FYM: *** IR: ** Treatment: ** Block*FYM: NS, FYM*IR: NS^b, Block*FYM*IR: *, Treatment*FYM: NS, Treatment*IR: NS, Treatment*FYM*IR: NS

LSD (P=0.05) Block: 0.46, FYM:0.38, IR:0.46, Treatment: 0.53

* Significant at 5% level, ** Significant at 1% level.

^aUsing block*FYM type III mean squares as an error term

^bUsing Block*FYM*IR type III mean squares as an error term

Table 2. Potato tuber yield (q ha⁻¹) under various FYM levels, irrigation regimes, and fertilizer sources during the year 2012

Irrigation regime	Tuber yield (q ha ⁻¹)									
	FYM ₀					FYM ₅₀				
	T0	T1	T2	T3	Mean	T0	T1	T2	T3	Mean
IR ₁	99.8	145.8	160.2	157.8	140.9	149.1	204.7	235.1	245.8	208.7
IR ₂	98.3	123.8	146.9	150.2	129.8	119.8	213.7	220.7	220.0	193.6
IR ₃	89.1	127.4	123.6	123.1	115.8	139.6	200.5	209.2	220.3	192.4
Mean	95.7	132.3	143.6	143.7	128.8	136.2	206.3	221.7	228.7	198.2
Significance level	Block: NS, FYM: **a, Block*FYM: NS, IR: **b, FYM*IR: NS ^b , Block*FYM*IR: *, Treatment:**, Treatment*FYM: **, Treatment*IR: NS, Treatment*IR*FYM: NS									
LSD (P=0.05)	Block: NS, FYM:8.0, IR: 9.8, Treatment: 11.3									

Irrigation Regime	IWUE (q tuber ha ⁻¹ cm ⁻¹)									
	FYM ₀					FYM ₅₀				
	T0	T1	T2	T3	Mean	T0	T1	T2	T3	Mean
IR ₁	3.99	5.83	6.41	6.31	5.64	5.96	8.19	9.40	9.84	8.35
IR ₂	4.91	6.19	7.35	7.51	6.49	5.99	10.69	11.03	11.00	9.68
IR ₃	4.45	6.37	6.18	6.16	5.79	6.98	10.02	10.46	11.02	9.62
Mean	4.45	6.13	6.65	6.66	5.97	6.31	9.63	10.30	10.62	9.22
Significance level	Block: NS, FYM: **a, Block*FYM: NS, IR: **b, FYM*IR: NS ^b , Block*FYM*IR: *, Treatment:**, Treatment*FYM: **, Treatment*IR: NS, Treatment*IR*FYM: NS									
LSD (P=0.05)	Block: NS, FYM: 0.36, IR: 0.45, Treatment: 0.52									

* Significant at 5% level, ** Significant at 1% level.

^aUsing block*FYM type III mean squares as an error term

^bUsing Block*FYM*IR type III mean squares as an error term

experimental field during the first year. This is also substantiated by the significant block effect in the first year. The 2012 contrasts again reinforce the point that DAP or NPK complex fertilizer in general outperformed the straight fertilizers (Contrast T1 vs. T2, T1 vs. T3).

The results of other contrasts reveal that in the presence of FYM during the second year T3 performed significantly better than T1. Given the adequate availability of water (IR₁), both T2 and T3 performed significantly better than T1. Mahapatra *et al.* (2007) also found NPK (10:26:26) to be better than the combined use of urea, single superphosphate, and muriate of potash. However, under water stressed environments (IR₂ and IR₃), all the fertilizer sources failed to show their specific effect.

The better yield and water use response from the treatments involving use of DAP (T2) and NPK complex fertilizer (T3) can be ascribed to even application and easy availability of nutrients in the root environment (FAO, 2000), higher available (neutral ammonium citrate soluble) P content with lesser water soluble P content (89% of available P content in DAP, 85% in NPK as compared to 100% in single superphosphate) and hence lesser fixation and more sustained availability of phosphorus.

Single degree of freedom contrasts in IWUE showed that during the second year T3 demonstrated significantly better IWUE than T1 (Table 3). However, during the year 2011, this trend was observed only in the absence of FYM. On the contrary, during the year 2012, T3 showed significantly higher IWUE than T1. Under adequate moisture supply conditions (IR₁), both T2 and T3 stood significantly higher than T1 in IWUE. T3, however, showed the highest IWUE.

Overall, the results lead to the conclusion that there exists general evidence during the first year and statistical evidence during the second year in favour of the higher yield and water use efficiency benefits from the treatments that involve the use NPK complex and DAP fertilizer, over the straight fertilizers,

Table 3. Results of some *a priori* single degree of freedom tuber yield contrasts

Contrast	Prob>F	
	2011	2012
T1 vs. T2	0.1168	0.0222*
T1 vs. T3	0.9629	0.0044**
T2 vs. T3	0.1068	0.5223
T1 vs. T2 without FYM	0.7715	0.1616
T1 vs. T3 without FYM	0.1755	0.1574
T2 vs. T3 without FYM	0.1027	0.9882
T1 vs. T2 with FYM	0.0554	0.0587
T1 vs. T3 with FYM	0.1966	0.0072*
T2 vs. T3 with FYM	0.5106	0.3747
T1 vs. T2 with IR ₁	0.1584	0.0257*
T1 vs. T3 with IR ₁	0.8903	0.009**
T2 vs. T3 with IR ₁	0.2013	0.6673
T1 vs. T2 with IR ₂	0.1903	0.1273
T1 vs. T3 with IR ₂	0.9613	0.0985
T2 vs. T3 with IR ₂	0.2066	0.8931
T1 vs. T2 with IR ₃	0.9935	0.8019
T1 vs. T3 with IR ₃	0.7897	0.4272
T2 vs. T3 with IR ₃	0.7834	0.5855

* Significant at 5% level, ** Significant at 1% level.

Table 4. Results of some *a priori* single degree of freedom IWUE contrasts

Contrast	Prob>F	
	2011	2012
T1 vs. T2	0.1350	0.0262
T1 vs. T3	0.9274	0.0052
T2 vs. T3	0.1138	0.5145
T1 vs. T2 without FYM	0.8457	0.1625
T1 vs. T3 without FYM	0.1785	0.1505
T2 vs. T3 without FYM	0.1256	0.9657
T1 vs. T2 with FYM	0.057	0.0722
T1 vs. T3 with FYM	0.2221	0.0095**
T2 vs. T3 with FYM	0.4739	0.3806
T1 vs. T2 with IR ₁	0.1791	0.0498**
T1 vs. T3 with IR ₁	0.895	0.0209**
T2 vs. T3 with IR ₁	0.224	0.7015
T1 vs. T2 with IR ₂	0.2133	0.0969
T1 vs. T3 with IR ₂	0.9649	0.0722
T2 vs. T3 with IR ₂	0.2294	0.8834
T1 vs. T2 with IR ₃	0.9912	0.7808
T1 vs. T3 with IR ₃	0.7387	0.3813
T2 vs. T3 with IR ₃	0.7305	0.5483

* Significant at 5% level. ** Significant at 1% level.

for meeting phosphorus needs of the crop in a sustained manner. These benefits may have been due to better balanced availability of nutrients in compound or complex fertilizers. However, these benefits are observed only under adequate moisture supply conditions. Under water stressed environments, these benefits get confounded. Further, generally higher prices associated with complex fertilizers may undo their benefits over straight fertilizers.

References

- Ezzat, A.E., A.A. El-Awady and H.M.I. Ahmed, 2011. Improving nitrogen utilization efficiency by potato (*Solanum tuberosum* L.) *Nature and Science*, 9: 34-42.
- Fabeiro, C., F. Martin de Santa Olalla and J.A. de Juan, 2001. Yield and size of deficit irrigated potatoes. *Agric. Water Manage.*, 48: 255-266.
- FAO, 2000. *Fertilizers and Their Use. A Pocket Guide for Extension Officers*. Food and Agriculture Organization of United Nations. International Fertilizer Industry Association Rome, p. 34.
- Govt. of India, 2013. *Pocket Book on Agricultural Statistics*. Ministry of Agriculture, New Delhi. p.102.
- Gupta, B.R., T.P. Tiwari, R. Tiwari and K.N. Tiwari, 2007. Rebalancing nutrient application in late- sown potato. *Better Crops*, 91: 10-11.
- Kulhanek, M., J. Balik, J. Cerny, K. Schweitzer, V. Vanek and M. Prasilova, 2008. Evaluation of phosphorus quantity/intensity parameters in soil with different systems of organic fertilising. *Plant Soil Environ.*, 54: 389-394.
- Li, S., Y. Duan, T. Guo and Y. Zhang, 2011. Demonstrating a link between nutrient use and water management to improve crop yields and nutrient use efficiency in arid northwest China. *Better Crops*, 95: 20-22.
- Mahapatra, B.K., S. Maiti and M. Satpathi. 2007. Relative performance of complex and straight chemical fertilizer in conjunction with and without organic manure in potato-jute crops sequence. *J. Crop Weed*, 3: 52-56.
- Porter, G.A., G.B. Opena, W.B. Bradbury, J.C. McBurnie and J.A. Sisson, 1999. Soil management and supplemental irrigation effects on potato. I. Soil properties, tuber yield, and quality. *Agron. J.*, 91: 416-425.
- Roy, R.N., A. Finck, G.J. Blair and H.L.S. Tandon, 2006. Plant nutrition for food security. A guide for integrated nutrient management. *FAO Fertilizer and Plant Nutrition Bull.*, 16: 368. Food and Agriculture Organization of the United Nations, Rome, Italy.
- Vos, J. 2009. Nitrogen responses and nitrogen management in potato. *Potato Res.*, 52: 305-317.

Received: August, 2014; Revised: November, 2014;
Accepted: December, 2014