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Research Paper

Nutrition management effects on productivity and tuber quality of potato (*Solanum tuberosum*)

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2014–15 and 2015–16 at Ludhiana, Punjab to study the effect of nutrition management on productivity, quality, disease incidence and storage behaviour of potato (*Solanum tuberosum* L.) tubers. Nutrition-management treatments comprised T_1, $F_{100}N_{100}P_{100}K_{100}$ (100% of recommended dose of manures and fertilizers [RDMF] i.e. 50 t FYM + 187.5 kg N + 62.5 kg P_2O_5 + 62.5 kg K_2O/ha); T_2, $F_{50}N_{75}P_{100}K_{100}$; T_3, $F_{50}N_{75}P_{150}K_{150}$; T_4, $F_0N_{75}P_{100}K_{100}$; T_5, $F_0N_{75}P_{150}K_{150}$; T_6, $F_0N_{75}P_{200}K_{200}$; T_7, $F_0N_{100}P_{100}K_{100}$; T_8, $F_0N_{100}P_{150}K_{150}$; T_9, $F_0N_{100}P_{200}K_{200}$ and T_{10}, $F_0N_0P_0K_0$ (unfertilized control). The tuber yield, storage behaviour of and disease incidence on potato tubers relied on the pre-harvest application of manures and fertilizers. The highest tuber yield was obtained with T_1, RDMF (39.49 t/ha) and it was statistically at par with treatments T_3, $F_{50}N_{75}P_{150}K_{150}$ and $T_9F_0N_{100}P_{200}K_{200}$. The lowest tuber yield was obtained in the unfertilized control (T_{10}) (20.86 t/ha). Nutrition-management practices did not cause significant variations in quality characteristics of potato tubers. The lowest incidence and severity of potato scab and scurf was observed with treatment T_1 (RDMF), being statistically at par with T_2, T_3, T_8, and T_9 treatments in case of scurf and with T_2, and T_3 treatments in case of scab. The lowest sprouting, total weight loss and rottage were recorded with T_1 (RDMF) and the highest value of these parameters was observed with unfertilized control.

Key words : Disease incidence, Farmyard manure, Inorganic fertilizers, Nutrition management, Potato, Quality, Storage

Potato is the most important food crop in the world after wheat, rice and maize and is cultivated worldwide under diverse climatic conditions. In India, it is grown throughout the year in one or the other part of the country. India ranks second in its production and acreage after China in the world (FAOSTAT, 2020). Potato is ideally suited to meet the growing food demand associated with population growth in the country. Adequate nutrient supply is an essential agronomic practice to improve the productivity and quality of potato to meet the current demand. Potato is highly responsive to application of organic manures, and farmers invariably apply farmyard manure (FYM). However, owing to diverse uses of FYM at household level, e.g. as fuel, dung cakes (Mondal *et al.,* 2005), there is shortage of FYM as manure. Thus, farmers have to supplement the nutrient supply to the crop with chemical fertilizers.

In India, 90% of the potatoes are grown in subtropical plains as winter crop (Gupta *et al.,* 2015) and is harvested in February/ March when the temperature and humidity begin to rise sharply. Under such conditions, the tubers break their dormancy and begin to sprout, resulting in shrinkage, weight loss and rot (Devendra *et al*., 1995). Due to oversupply of potato, the prices are at their lowest during this period which force the growers to retain the produce till May when the prices start rising making storage of potato tubers important. The on-farm storage can provide an effective alternate to potato growers and processors to retain their produce. Nutrition-management practices can also play an important role to increase the storability of potatoes. Keeping quality characters such as physiological weight losses, total weight losses, decay losses and sprouting behaviour of potato tubers have been found to be influenced by nutrition-management practices (Kumar *et al.,* 2011). Also, nutrient management is considered as the most important line of defense against the plant diseases (Datnof *et al*., 2007). Several studies have reported the decreased

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disease incidence in potato tubers with adequate NPK fertilization (Trehan *et al.,* 2009; Khalid *et al.,* 2015). In light of these, the present study was planned to investigate the effect of nutrition-management practices on tuber yield, quality, storage behaviour and disease incidence on tubers.

MATERIALS AND METHODS

The field experiment was carried out during the winter (*rabi*) season of 2014–15 and 2015–16 at the Agronomy Research Farm, Punjab Agricultural University, Ludhiana, India, representing the Indo-Gangetic alluvial plains situated at 30º56' N and 75º52' E with an altitude of 247 m above the sea-level. The experimental site has subtropical to semi-arid climate with hot and dry summer (April to June), hot and humid monsoon (July to September), mild winter (October to November) and cold winter (December to February). The mean minimum and maximum temperatures reveal considerable fluctuation during the summer and winter; maximum air temperature above 38°C is common during the summer and frequent frosty spells in December–January. The average annual rainfall at Ludhiana is 755 mm, 75% of which is received in the summer monsoon (July to September) complemented by a few showers of low to medium intensity in winter.

The experiment was conducted in randomized complete-block design, replicated thrice to study the effect of nutrition-management comprising treatments of T_1, $F_{100}N_{100}P_{100}K_{100}$ (100% of recommended dose of manures and fertilizers [RDMF] i.e. 50 t FYM + 187.5 kg N + 62.5 kg P_2O_5 + 62.5 kg K_2O/ha); T_2, $F_{50}N_{75}P_{100}K_{100}$; T_3, $F_{50}N_{75}P_{150}K_{150}$; T_4, $F_0N_{75}P_{100}K_{100}$; T_5, $F_0N_{75}P_{150}K_{150}$; T_6, $F_0N_{75}P_{200}K_{200}$; T_7, $F_0N_{100}P_{100}K_{100}$; T_8, $F_0N_{100}P_{150}K_{150}$; T_9, $F_0N_{100}P_{200}K_{200}$ and T_{10}, $F_0N_0P_0K_0$ (unfertilized control)

The soil of experimental site was loamy sand in texture with neutral *p*H (7), medium organic carbon (0.45%), low available N (252 kg/ha), high available P (42.1 kg/ha) and medium available K (318 kg/ha). The electrical conductivity was within the normal range (0.24 m mhos/cm). Potato cultivar 'Kufri Pukhraj' was sown in mid-October by using medium-sized (35–45 mm) seed tubers at inter-and intra-row spacing of 65 and 11.5 cm, respectively. Other crop-management practices were as per the local package of practices of the PAU (Package of Practices for Cultivation of Vegetables, 2014–15). Haulm cutting was done in the first week of January and the crop was harvested in end January.

Dry-matter accumulation by tubers and haulm was determined at 30, 45, 60 days after sowing (DAS) and at haulm cutting. Total soluble solids were determined by hand refractometer. The titrimetric method using 2, 6-dichlorophenol-indophenol dye was used to estimate ascorbic acid. Total phenolic content was determined by modification of Folin-Ciocalteu's colorimetric method. Subsequently, tubers were kept under shade for 15 days for proper curing of tuber skin. These skin-cured tubers were used for study on storage behaviour of tubers. Five kg clean and uniform sized (35–45 mm) tubers from each treatment were taken in Hessian cloth bags and kept at room temperature, allowing sufficient space for air movement between the bags, in mid-February during both the years. Sprouting of tubers was observed at 30 days interval up to 90 days of storage (DOS) by randomly selecting 50 tubers from each set. The tubers having sprouts more than 2 mm length were considered as sprouted. The sprouting percentage was calculated as:

$$\text{Sprouting (\%)} = \frac{\text{Number of sprouting tubers}}{\text{Total number of tubers}} \times 100$$

The length of 5 longest sprouts on the tubers was measured at 30, 60, and 90 DOS and average was reported as sprout length (mm). Total weight of tubers at 30, 60 and 90 DOS was recorded and the per cent weight loss was calculated as:

$$\text{Total tuber weight loss (\%)} = \frac{\text{Initial weight of tubers} - \text{Final weight of tubers}}{\text{Initial weight of tubers}} \times 100$$

Tuber rottage by number and weight was observed at 30, 60 and 90 DOS by randomly selecting 50 tubers from the lot. The rottage percentage was calculated by the formula:

$$\text{Rottage (\%)} = \frac{\text{Number/weight of rotted tubers}}{\text{Total number/weight of tubers}} \times 100$$

For observations on scurf and scab infection, hundred potato tubers were randomly selected from each plot at the time of harvesting to determine disease incidence and severity. Disease incidence (%) was calculated on the basis of number of infected tubers.

$$\text{Disease incidence (\%)} = \frac{\text{No. of infected tubers}}{\text{Total tubers/weight of tubers}} \times 100$$

Disease severity was calculated based on the symptom on the surface of the tuber. Hundred tubers were selected randomly and categorized into 0-5 scale and finally percentage of disease incidence was calculated as:

Disease-severity scale

Disease-severity grade	Scurf severity (% tuber surface affected)	Scab severity
0	No disease	No disease symptoms
1	< 1	Very small lesions
2	1–10	Small superficial lesions
3	11–20	Periderm broken
4	21–50	Light pitted
5	> 50	Deep pitted

Statistical analyses of the data were carried out using PROC GLM in SAS 9.4 software (SAS INC, Cary NC). Multiple comparisons were made using LSD at $P \leq 0.05$ to determine significant effects. The data on % rottage (number and weight) were transformed ($\sqrt{x + 0.5}$) for statistical analysis.

RESULTS AND DISCUSSION

Dry-matter accumulation in tubers and haulm

Dry matter accumulation (DMA) reflects the growth, development and photosynthetic efficiency of the plants, ultimately determining the final crop yield. Pooled data of 2 years revealed that, DMA by tubers and haulm increased with the advancement of the crop stage up to haulm cutting (Table 1). At all the growth stages, tuber and haulm DMA was the highest with treatment T_1 (RDMF) and it was statistically at par with T_3 $F_{50}N_{75}P_{150}K_{150}$ and T_9 $F_0N_{100}P_{200}K_{200}$ treatments. The lowest tuber and haulm DMA was recorded in treatment T_{10} (unfertilized control) at all the growth stages.

Among the treatments where FYM was applied (T_1–T_3), the highest tuber and haulm DMA at all the growth stages was obtained with treatment T_1 (RDMF) and it was statistically at par with treatment T_3, $F_{50}N_{75}P_{150}K_{150}$ at most of the growth stages but significantly higher than T_2, $F_{50}N_{75}P_{100}K_{100}$. Among the non-FYM treatments (T_4–T_9), the highest DMA of tubers and haulm was recorded with treatment T_9, $F_0N_{100}P_{200}K_{200}$, being statistically at par with treatment T_8, $F_0N_{100}P_{150}K_{150}$ but significantly higher than all the other treatments. The higher DMA with the application of higher dose of nutrients showed positive response of this crop to the higher availability of nutrients. It is evident that application of nutrients through integration of inorganic fertilizers with FYM gave better results of DMA in tubers and haulm. However, in case of unavailability of FYM, similar results can be obtained with increased level of P and K nutrients with chemical fertilizers. Mondal *et al.* (2005) also reported the maximum tuber DMA under the treatment in which N, P and K were applied along with FYM. Rani (2012) reported the highest plant DMA with recommended dose of fertilizers (RDF) along with FYM and it was statistically at par with 125% RDF alone but significantly higher than 75 and 100% RDF alone.

Tuber yield

Nutrient-management practices exerted a significant effect on tuber yield of potato. The highest tuber yield was obtained with treatment T_1, RDMF (39.49 t/ha) and it was statistically at par with treatments T_3, $F_{50}N_{75}P_{150}K_{150}$ and T_9, $F_0N_{100}P_{200}K_{200}$ but significantly higher than all the other treatments (Table 1). The lowest tuber yield was obtained in the unfertilized control (T_{10}) which resulted in 47.18% lower tuber yield than treatment T_1 (RDMF). Among the FYM treatments (T_1–T_3), the highest total tuber yield was obtained with treatment T_1 (RDMF) and it was statistically at par with the treatment T_3, $F_{50}N_{75}P_{150}K_{150}$, but significantly higher than treatment T_2, $F_{50}N_{75}P_{100}K_{100}$. Among the no-FYM treatments (T_4–T_9), the highest tuber yield was obtained with treatment T_9, $F_0N_{100}P_{200}K_{200}$ (38.50 t/ha) and it was statistically at par with treatment T_8, $F_0N_{100}P_{150}K_{150}$ but significantly higher than rest of the treatments. The results indicated that higher tuber yield was obtained with the application of recommended dose of FYM and fertilizers or with increased dose of inorganic fertilizers P and K in the absence of FYM which might be owing to positive response of this crop to the availability of these nutrients. Kumar *et al.* (2011) also reported the highest tuber yield with the application of NPK through combined use of inorganic fertilizers (50%) and organic manures (50%) and it was statistically at par with 100% recommended dose of

Table 1. Effect of nutrition management on dry-matter accumulation (DMA) and tuber yield of potato (pooled analysis)

Treatment	DMA in tubers				DMA in haulm				Tuber
	30 DAS	45 DAS	60 DAS	At HC	30 DAS	45 DAS	60 DAS	At HC	Yield(t/ha)
T_1, $F_{100}N_{100}P_{100}K_{100}$	9.10	22.00	40.78	60.34	5.42	8.77	12.90	13.08	39.49
T_2, $F_{50}N_{75}P_{100}K_{100}$	7.20	17.83	34.49	51.17	4.58	7.94	11.23	11.34	34.16
T_3, $F_{50}N_{75}P_{150}K_{150}$	8.29	20.10	38.68	55.18	5.13	8.45	12.53	12.62	37.92
T_4, $F_0N_{75}P_{100}K_{100}$	4.69	14.09	27.54	42.99	3.68	5.93	9.63	9.85	28.38
T_5, $F_0N_{75}P_{150}K_{150}$	6.36	17.07	33.57	50.60	4.52	7.28	11.13	11.61	33.65
T_6, $F_0N_{75}P_{200}K_{200}$	7.06	17.74	34.40	51.82	4.65	7.68	11.31	11.77	33.92
T_7, $F_0N_{100}P_{100}K_{100}$	5.52	16.30	30.07	46.30	3.85	6.61	10.03	10.35	31.60
T_8, $F_0N_{100}P_{150}K_{150}$	8.33	19.83	37.28	55.69	5.10	8.52	12.27	12.42	36.70
T_9, $F_0N_{100}P_{200}K_{200}$	8.87	21.07	38.93	57.60	5.29	8.68	12.62	12.81	38.50
T_{10}, $F_0N_0P_0K_0$	3.70	8.33	19.08	28.23	2.80	3.57	6.82	6.51	20.86
SEm±	0.23	0.65	0.95	1.26	0.13	0.16	0.27	0.22	0.92
CD ($P \leq 0.05$)	0.65	2.63	2.66	3.69	0.40	0.45	0.80	0.66	2.64

Details of treatments are given under Materials and Methods; DMA, Dry-matter accumulation; DAS, days after sowing; HC, haulm cutting

NPK through inorganic fertilizers. Baishya *et al*. (2010) also reported the increased potato tubers yield with the application of recommended dose of nutrients through inorganic fertilizers or with integrated use of inorganic fertilizers and FYM.

Tuber quality

The nutrition-management practices did not exert a significant effect on total soluble solids (TSS), ascorbic acid, total phenols and specific gravity of potato tubers (Fig. 1). However, the highest value of these quality traits was recorded with treatment T_1 (RDMF) and the lowest with treatment T_{10} (unfertilized control) which might be due to adequate availability of nutrients from applied manures and fertilizers.

Tuber sprouting

Sprouting, a major problem of storage, makes the potato tuber unfit for human consumption and seed purpose due to physiological loss in weight and shrinkage. In present study, the sprouting of tubers started at 30 days of storage (DOS) in all the treatments and it increased progressively (Table 2). At all the stages of storage, i.e. 30, 60 and 90 DOS, the lowest sprouting (12.0, 47.0 and 66.7%, respectively) was recorded with treatment T_1 (RDMF) and it was statistically at par with other FYM treatments (T_2, $F_{50}N_{75}P_{100}K_{100}$ and T_3, $F_{50}N_{75}P_{150}K_{150}$). However, the most of the no-FYM treatments exhibited significantly higher sprouting. The highest sprouting was observed with treatment T_{10} (unfertilized control) at all the stages of storage and it showed 69.17, 27.02 and 25.94% higher sprouting than that of treatment T_1 (RDMF) at 30, 60 and 90 DOS respectively. The differences in treatments with the highest and the lowest sprouting of tubers decreased with the increased duration of storage. Sharma and Sud (2001) also reported reduced sprouting of tubers with 150 kg K/ha as compared to 0, 50 and 100 kg K/ha. This could be due to the influence of K on the enzymatic activities at sprouting tuber eyes (Havlin *et al*., 2005). Also, K helps to slow down the senescence and reduce the physiological disorders in storage thus improving shelf life (Bhattarai and Swarnima, 2016) which may have reduced sprouting in treatments with increased K application.

Sprout length

Pooled data of 2 years showed that sprout length was significantly influenced by the nutrition-management practices (Table 2). At all the stages of storage, i.e. 30, 60 and 90 DOS, the longest sprout length (6.1, 17.0 and 20.0 mm respectively) was recorded with treatment T_1 (RDMF) and it was statistically at par with T_9, $F_0N_{100}P_{200}K_{200}$. At 60 and 90 DOS, the treatments T_3, $F_{50}N_{75}P_{150}K_{150}$; T_6, $F_0N_{75}P_{200}K_{200}$; and T_9, $F_0N_{100}P_{200}K_{200}$ were also statistically at par with treatment T_1 with respect to sprouting length. The shortest sprout length, during the whole storage period, was observed with unfertilized control. The sprout length increased with increased level of nutrients either through inorganic fertilizers or FYM which might have contributed towards increased growth of sprouts after their initiation.

Tuber weight loss

The loss in weight of tubers during storage is caused by physiological loss and decay during storage. The present study showed that per cent weight loss increased progressively with increase in the storage period, and the rate of increase was higher at later as compared to earlier stages of

Table 2. Influence of nutrition management on sprouting, weight loss and rottage of harvested tubers at 30, 60 and 90 days of storage (pooled data)

Treatment	Sprouting (%)			Sprout length (mm)			Total weight loss (%)			Rottage (%)	
	30	60	90	30	60	90	30	60	90	by number 90	by weight 90
T_1, $F_{100}N_{100}P_{100}K_{100}$	12.0	47.0	66.7	6.09	17.0	20.0	1.69	6.84	13.5	0.00 (1.00)*	0.00 (1.00)
T_2, $F_{50}N_{75}P_{100}K_{100}$	14.0	50.0	70.0	4.82	14.4	18.7	1.79	7.18	13.9	1.33 (1.41)	1.25 (1.40)
T_3, $F_{50}N_{75}P_{150}K_{150}$	12.3	48.3	68.3	5.04	16.3	19.5	1.73	7.00	13.6	0.00 (1.00)	0.00 (1.00)
T_4, $F_0N_{75}P_{100}K_{100}$	17.7	56.7	80.0	3.80	9.5	15.4	1.94	7.72	14.9	2.67 (1.82)	2.47 (1.78)
T_5, $F_0N_{75}P_{150}K_{150}$	14.0	51.0	72.7	4.27	11.8	17.4	1.72	7.43	13.9	1.33 (1.41)	1.08 (1.35)
T_6, $F_0N_{75}P_{200}K_{200}$	12.7	49.7	70.7	5.06	15.4	18.6	1.56	6.97	13.6	0.00 (1.00)	0.00 (1.00)
T_7, $F_0N_{100}P_{100}K_{100}$	19.0	59.0	81.0	4.09	10.1	16.7	2.10	7.84	15.2	4.00 (2.23)	3.53 (2.14)
T_8, $F_0N_{100}P_{150}K_{150}$	15.7	53.3	75.0	4.42	14.1	18.8	1.80	7.53	14.2	1.33 (1.41)	1.24 (1.39)
T_9, $F_0N_{100}P_{200}K_{200}$	14.3	52.0	72.7	5.44	16.0	19.9	1.67	7.14	13.7	1.33 (1.41)	0.94 (1.32)
T_{10}, $F_0N_0P_0K_0$	20.3	59.7	84.0	3.61	8.9	13.5	2.42	8.27	15.5	5.33 (2.49)	3.89 (2.20)
SEm±	0.69	1.12	1.2	0.41	0.68	0.69	0.16	0.25	0.21	0.30	0.27
CD ($P \leq 0.05$)	2.0	3.2	3.4	0.86	2.0	1.9	0.46	0.69	0.6	(0.90)	(0.80)

Details of treatments are given under Materials and Methods

Figures in parentheses are transformed means storage (Table 2). At 30 DOS, the tuber weight loss was the minimum (1.56%) with treatment T_6, $F_0N_{75}P_{200}K_{200}$ and it was statistically at par with all the treatments except T_7, $F_0N_{100}P_{100}K_{100}$ and T_{10} (unfertilized control). At 60 and 90 DOS, the minimum weight loss (6.84 and 13.47%, respectively) was observed with treatment T_1 (RDMF) and it was statistically at par with treatment T_2, $F_{50}N_{75}P_{100}K_{100}$; T_3, $F_{50}N_{75}P_{150}K_{150}$; T_5, $F_0N_{75}P_{150}K_{150}$; T_6, $F_0N_{75}P_{200}K_{200}$; and T_9, $F_0N_{100}P_{200}K_{200}$. The maximum weight loss was recorded with treatment T_{10} (unfertilized control) at all the storage stages and it was 43.19, 20.91 and 14.81% higher than treatment T_1 (RDMF) at 30, 60 and 90 DOS, respectively. The tuber weight loss during storage was less with integration of chemical fertilizers with FYM or with higher dose of inorganic P and K fertilizers to the crop. The decrease in weight loss of tubers with increased levels of P and K might be due to the fact that tubers harvested from higher P and K treatments were less susceptible to shriveling and moisture loss during storage. Singh and Lal (2012) also reported reduced weight loss in tubers with increased dose of K as compared to no-K fertilization. The total tuber weight loss is made up of the sum of the losses due to sprouting, respiration and evaporation. Sprouting has been found to increase the respiration, thus, considered as one of the major factors affecting the weight losses occurring during storage (van Es and Hartmans, 1987). In the present study, sprouting was reduced with increased nutrient application, which may have reduced the respiration and thus, reduced weight loss of tubers during the storage.

Tuber rottage

Tuber rottage is the major problem of storage, as it deteriorates the quality of potato and makes it unfit for human consumption and seed purpose. The nutrition management exerted a significant effect on number- and weight-based rottage of tubers. The lowest rottage by number and weight was recorded with treatment T_1 (RDMF) and T_3, $F_{50}N_{75}P_{150}K_{150}$ and it was statistically at par with all the treatments except T_7, $F_0N_{100}P_{100}K_{100}$ and T_{10} (unfertilized control). The highest rottage by number and weight (2.49 and 2.20%, respectively) was observed with treatment T_{10} (unfertilized control), followed by treatment T_7, $F_0N_{100}P_{100}K_{100}$. The tuber rottage, both by number and weight basis, decreased with the combined application of FYM and chemical fertilizers and with increased level of P and K fertilizers. However, increased level of N enhanced the rottage both by number and weight basis. Singh and Lal (2012) also reported the decreased rottage of stored tubers with increased dose of K under ordinary storage conditions. The effect of K on rottage may be due to the effect of K on slowing of senescence and through decrease of numerous physiological disorders (Bhattarai and Swarnima, 2016).

Correlation among different storage parameters

Correlation coefficients among different attributes of storability were analyzed for all the combinations (Table 3). The sprouting at 30 DOS was significantly and negatively correlated with sprout length (mm) at 30, 60 and 90 DOS (R= –0.84, –0.91, –0.87, respectively). Similarly, the sprouting at 60 and 90 DOS showed a significant and negative correlation with sprout length at different stages of storage. A significant positive correlation existed between sprouting at 30 DOS and total tuber weight loss at 30, 60 and 90 DOS (R= 0.92, 0.97 and 0.99, respectively). Similar trend of correlation was recorded between sprouting at 60 and 90 DOS and total tuber weight loss at 30, 60 and 90 DOS. The sprouting at 30 DOS showed a significant positive correlation with number-based (R= 0.98) and weight-based rottage (R= 0.98) at 90 DOS. The sprouting at 60 and 90 DOS was also highly significant and positively correlated with number-based and weight-based rottage (%) at

Table 3. Correlation coefficient between storage parameters

Parameter	Spr_{30}	Spr_{60}	Spr_{90}	SL_{30}	SL_{60}	SL_{90}	WL_{30}	WL_{60}	WL_{90}	RN_{90}
Spr_{60}	0.99*									
Spr_{90}	0.99*	0.99*								
SL_{30}	–0.84*	–0.84*	–0.87*							
SL_{60}	–0.91*	–0.90*	–0.92*	0.93*						
SL_{90}	–0.87*	–0.85*	–0.89*	0.88*	0.95*					
WL_{30}	0.92*	0.87*	0.87*	–0.72*	–0.79*	–0.85*				
WL_{60}	0.97*	0.95*	0.96*	–0.91*	–0.93*	–0.93*	0.92*			
WL_{90}	0.99*	0.97*	0.97*	–0.85*	–0.93*	–0.91*	0.93*	0.96*		
RN_{90}	0.98*	0.95*	0.95*	–0.80*	–0.89*	–0.88*	0.96*	0.96*	0.97*	
RW_{90}	0.98*	0.97*	0.95*	–0.82*	–0.91*	–0.87*	0.93*	0.95*	0.98*	0.99*
$P \leq 0.05$										

Spr, sprouting; SL, sprout length; WL, total weight loss; RN, number based rottage; RW, weight based rottage; 30, 60 and 90 means storage parameters at 30, 60 and 90 days of storage, respectively

90 DOS. Sprout length at 30 DOS had a significantly negative correlation with total weight loss at 30, 60 and 90 DOS, number-based and weight-based rottage at 90 DOS (R= –0.72, –0.91, –0.85, –0.80 and –0.82 respectively). Similarly, a significant negative correlation of sprout length at 60 and 90 DOS was observed with total tuber weight loss, number- and weight-based rottage at different storage periods. The total tuber weight loss at 30 DOS had a significant positive correlation with number- and weight-based rottage at 90 DOS (R= 0.96 and R= 0.93 respectively). Similarly, total tuber weight loss at 60 and 90 DOS showed a significant and positive correlation with number- and weight-based rottage at 90 DOS. Correlation coefficient between number based rottage at 90 DOS was significant and positive with the weight based rottage at 90 DOS (R= 0.99). The analysis of correlation coefficient indicated that sprouting in tubers during storage induced the total weight loss and number- and weight-based rottage percentage of tubers. Roy *et al*. (2006) also reported that, rottage percentage had a significant positive correlation with weight loss but a negative correlation with apical sprout length. Gupta *et al.* (2015) also found that, sprouting percentage at 75 DOS had highly significant positive correlation with per cent physiological weight loss and per cent total weight loss. Similarly, per cent rottage by weight had positive and significant correlation with total weight loss.

Disease incidence on potato tubers

The nutrition management in crop exerted a significant effect on the scurf and scab incidence and severity on harvested tubers (Table 4). The lowest incidence and severity of these diseases was observed with treatment T_1 (RDMF) and it was statistically at par with treatment T_2, $F_{50}N_{75}P_{100}K_{100}$; T_3, $F_{50}N_{75}P_{150}K_{150}$; T_8, $F_0N_{100}P_{150}K_{150}$; and T_9, $F_0N_{100}P_{200}K_{200}$ in case of scurf and with T_2, $F_{50}N_{75}P_{100}K_{100}$; and T_3, $F_{50}N_{75}P_{150}K_{150}$ in case of scab. The treatment T_{10} (unfertilized control) had the highest incidence and severity of both the diseases. Among the no-FYM treatments (T_4–T_9), the lowest scurf and scab incidence and severity was observed with treatment T_8, $F_0N_{100}P_{150}K_{150}$; and T_9, $F_0N_{100}P_{200}K_{200}$ and it was statistically at par with treatment T_5, $F_0N_{75}P_{150}K_{150}$; and T_6, $F_0N_{75}P_{200}K_{200}$ but significantly lower than rest of the treatments. Lower incidence and severity of scurf and scab with higher dose of nutrients (P and K) through inorganic fertilizers or organic manures might be due to the balanced supply of nutrients which suppressed the growth of pathogen and reduced the disease incidence severity. Trehan *et al.* (2009) reported decreased black scurf incidence in potato with K application. Khalid *et al.* (2015) also reported reduced incidence of common scab with application of NPK fertilizers.

In the present investigation, it was found that tuber yield, storage behaviour and disease incidence of potato relies on the pre-harvest application of manures and fertilizers. The recommended dose of FYM and fertilizers (50 t FYM + 187.5 kg N + 62.5 kg P_2O_5 + 62.5 kg K_2O/ha) re-

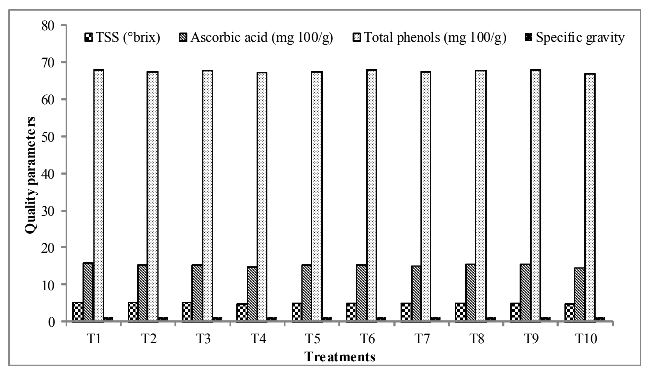

Fig. 1. Effect of nutrition management practices on quality of potato tubers (pooled analysis) (Details of treatments are given under Materials and Methods)

Table 4. Influence of nutrition management on disease incidence and severity in potato tubers

Treatment	Scurf (%)		Scab (%)	
	Incidence	Severity	Incidence	Severity
T_1, $F_{100}N_{100}P_{100}K_{100}$	1.83 (1.66)	0.37 (1.17)	4.67 (2.38)	0.93 (1.39)
T_2, $F_{50}N_{75}P_{100}K_{100}$	2.17 (1.76)	0.43 (1.20)	5.00 (2.44)	1.00 (1.41)
T_3, $F_{50}N_{75}P_{150}K_{150}$	2.00 (1.72)	0.40 (1.18)	4.67 (2.38)	0.93 (1.39)
T_4, $F_0N_{75}P_{100}K_{100}$	3.83 (2.16)	0.77 (1.32)	8.00 (3.00)	1.67 (1.63)
T_5, $F_0N_{75}P_{150}K_{150}$	2.83 (1.91)	0.57 (1.25)	6.67 (2.76)	1.33 (1.53)
T_6, $F_0N_{75}P_{200}K_{200}$	2.67 (1.88)	0.53 (1.23)	6.50 (2.74)	1.30 (1.52)
T_7, $F_0N_{100}P_{100}K_{100}$	3.33 (2.04)	0.67 (1.28)	7.50 (2.91)	1.50 (1.58)
T_8, $F_0N_{100}P_{150}K_{150}$	2.33 (1.80)	0.47 (1.21)	6.00 (2.64)	1.20 (1.48)
T_9, $F_0N_{100}P_{200}K_{200}$	2.33 (1.80)	0.47 (1.21)	6.00 (2.64)	1.27 (1.50)
T_{10}, $F_0N_0P_0K_0$	4.50 (2.31)	0.90 (1.37)	9.00 (3.16)	1.80 (1.67)
SEm±	(0.05)	(0.015)	(0.046)	(0.019)
CD (P≤0.05)	(0.15)	(0.04)	(0.13)	(0.05)

Details of treatments are given under Materials and Methods; Figures in parentheses are transformed means sults in higher total tuber yield. However, in case of non or less availability of sufficient quantity of FYM, similar yield can be obtained with increased levels of P and K up to 150% of recommended dose. Similarly, incidence and severity of scurf and scab can be lowered with combined application of fertilizers and FYM or with higher doses of P and K in absence of FYM. The tubers harvested from crop which received higher amount of nutrients in the form of FYM (25 to 50 t/ha) along with recommended dose of chemical fertilizers or 150% of inorganic P and K fertilizers were better in keeping quality attributes under ambient storage conditions.

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