



Effect of nitrogen sources on yield and yield components of potato (*Solanum tuberosum*) cultivars

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ABSTRACT

An experiment was conducted during two consecutive summer seasons to evaluate the effect of nitrogen sources on yield and yield attributing characters of potato (*Solanum tuberosum* L.) cultivars. The experiment was laid out in a factorial randomized block design with four potato cultivars and three different nitrogen sources. The sources of phosphorous (P) and potash (K) were single super phosphate (SSP) and muriate of potash (MOP) respectively where the nitrogen (N) source is urea and di-ammonium-phosphate. In case of di-ammonium phosphate (DAP) it served source for both N and P. The pooled analysis showed significant difference between cultivars, nitrogen sources and its interactions on all characters studied. Our results revealed that application of recommended dose of N in the form of urea in both basal as well as top dressing significantly increased the vegetative growth. However, N 75% supplied in the form of DAP as basal and remaining nitrogen 25% in the form of ammonium sulphate as top dressing (T₇) along with recommended dose of P and K and N 75% supplied in the form of ammonium sulphate as basal and 25% as top dressing (T₂) along with recommended P and K resulted maximum marketable tuber yield in terms of tuber number as well as weight. Therefore, for maximizing the marketable tuber yield N can be applied in the form of DAP and ammonium sulphate.

Key words: Ammonium sulphate, Potato, Source of nitrogen, Urea.

Potato (*Solanum tuberosum* L.) is the third most important food crops of the world after rice and wheat and mainstays the diet of people in many parts of the world. The present production scenario of potato in our country shows that India stands second after China in production with an estimated production of about 46.6 million tonnes from 2.17 million ha (FAO 2017). Hence sustaining the production potential in the most economical way is of important concern. The sustenance of optimum crop yield depends upon the adequacy and balance of macro and micro nutrients. Potato being a shallow rooted crop nutrient use efficiency is comparatively low as compared to cereal crops and it is reported that the fertilizer use efficiency of potato crop for N, P and K fertilizers are 40-50, 10-15 and 50-60% respectively (Tehran *et al.* 2008). Among the major nutrients, nitrogen is the first limiting nutrient in potato which has great influence on crop growth, tuber yield and its quality and it is the main component for the synthesis of

nucleic acids, proteins, chlorophyll etc. (Najm *et al.* 2012).

Potato is sensitive to application of nitrogen both in terms of time as well as quantity applied which will affect quality and quantity of tuber. Earlier studies showed that nitrogen fertilizers can increase the growth characters and tuber yield of potato (Muthoni and Kabira 2011). Hence sufficient use of nitrogen fertilizers in early growth stages expand leaf area and increase photo assimilates. The Indian soils are generally deficient in organic matter and thus unable to release nitrogen at the rate required for maintaining the adequate supply to the growing plant. Therefore, application of nitrogen in the form of fertilizers and manures are unavoidable to meet the needs of the crop. Sources of nitrogen, agro climatic zones and soil type affect potato crop response differentially and among the various nitrogen sources available, ammonium sulphate (21% N) has been found to be the best nitrogenous carrier for the potato (Tehran *et al.* 2008). But its relative shipping cost per unit of nitrogen is high because of its low nitrogen content. The most economical nitrogen source available is urea as it constitutes 46% N but in potato it is reported to be less efficient than other nitrogen fertilizers. The poor crop performance in urea is due to liberation of ammonia gas which damages sprout and roots at higher doses under warm dry soil conditions (Sharma and Grewel 1978). However,

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the advantages being relatively low cost nitrogen source and increase in performance if excessive rainfall occurs in the first few weeks after planting suggests its suitability as an alternative nitrogen source in successful potato crop. Di-ammonium phosphate (18% N) is another source of nitrogen even though it is a major source of phosphorus but their use is area specific (Tehran *et al.* 2008). In Southern hills, potato cultivation is mostly concentrated in the Nilgiri district of Tamil Nadu which has a unique agro climatic condition that favour the potato cultivation throughout the year in three seasons. The elevation of the region ranges between 1000 to 2500 m above MSL which falls under moist sub humid group of climatic classification. The proposed study was conducted to see the efficiency and feasibility of the different nitrogen sources, viz. ammonium sulphate, di-ammonium phosphate and urea in optimizing potato yield under rainfed conditions in the Nilgiris.

MATERIALS AND METHODS

The experiment was conducted at ICAR- Central Potato Research Station, Ooty in Nilgiri district of Tamil Nadu for two consecutive summer seasons during 2014 and 2015. The station was located at an altitude of 2140 m above MSL at 11°24' north latitude and 74°4' east longitude and the average annual rainfall of the site is 1300 mm. The main rainy season occurs between April and July while short rainy season is between August and October. The mean maximum temperature ranges between 17.5 and 22.2 °C and minimum temperature ranges between 7.3 and 12.3°C. The analysis of soil samples collected from the experimental site showed acidic pH of 4.4 and normal electrical conductivity (0.37 dS/m). The availability of N, P and K was medium, high and medium respectively and the organic carbon content was 1.7%. The experiment was laid out in a factorial randomized block design with four potato cultivars, viz. Kufri Jyoti, Kufri Swarna, Kufri Himalini, Kufri Girdhari and three different nitrogen sources (recommended dose), viz. ammonium sulphate (21% N), urea (46% N), di-ammonium phosphate (18% N). The nitrogen combination used in the study were T₁ - basal 100% ammonium sulphate; T₂ - 75% ammonium sulphate as basal + top dressing 25% ammonium sulphate; T₃ - 75% ammonium sulphate as basal + top dressing with 25% urea ; T₄ - 100% urea as basal; T₅ - 75% urea as basal + top dressing with 25% urea ; T₆ - basal (75% DAP+MOP) and top dressing with 25% urea ; T₇- basal (75% DAP + MOP) + top dressing with 25% ammonium sulphate giving a total of twenty eight treatment combinations altogether. These treatment combinations were replicated twice. Medium sized and well sprouted tubers of each cultivar were planted at 60 × 20 cm spacing in 3 × 3 m plot during second week of April. The experimental plots were applied with recommended dose of NPK 90:135: 90 kg/ha. The sources of phosphorous (P) and potash (K) were single super phosphate (SSP) and muriate of potash (MOP) respectively where the nitrogen (N) source is urea and ammonium sulphate. In case of di-ammonium phosphate (DAP) it served source for both N and P and the crop was

raised purely under rainfed condition.

During the growth period, observations, viz. germination percentage (45 days after planting), plant height, number of leaves and shoots (75 days after planting) were recorded. Haulm killing was done 15 days before harvesting and the crop was harvested at 120 days after planting. At the time of harvesting, yield parameters, viz. total number of tubers and weight per plot as well as marketable (>25 g) and non-marketable (<25 g) tuber number and weight was recorded. After harvesting, tuber yield/ha was computed based on total tuber yield/plot. Data were analyzed statistically by applying the technique of analysis of variance (ANOVA) as described by Panse and Sukhatme (1985). Mean values were calculated and separated using least significant difference test at the 5% significance level (LSD 5%).

RESULTS AND DISCUSSION

Growth parameters

The germination percentage and plant height were significantly influenced by treatments, cultivars and their interactions. Among the treatments, application of nitrogen in the form of urea 100% (T₄) as basal and 75% basal and 25% top dressing (T₅) significantly increased the germination percentage (68.66-68.92%) as well as plant height (43-43.25 cm). Among the cultivars Kufri Swarna showed maximum germination (71.42%), whereas maximum plant height (38.35 cm) was observed in Kufri Girdhari and was found to be on par with Kufri Swarna (37.10 cm). In the interaction, the treatments where nitrogen was applied in the form of urea 100% as basal (T₄) and 75% as basal and 25% as top dressing (T₅) significantly increased the height in Kufri Girdhari (51 and 45.75 cm), Kufri Swarna (42.25 and 42.50 cm) and Kufri Himalini (43.50 and 39.25 cm), whereas T₅ (45.50 cm) and T₆ (40.50 cm) significantly increased the plant height in Kufri Jyoti (Fig 1 and 2). The pooled analysis showed that the number of stems/plant was significantly influenced only by cultivars. Among the cultivars, Kufri Girdhari significantly recorded more number of stems (2.8) followed by Kufri Swarna (2.7) (Fig 3).

The yield of potato depends on many factors like other

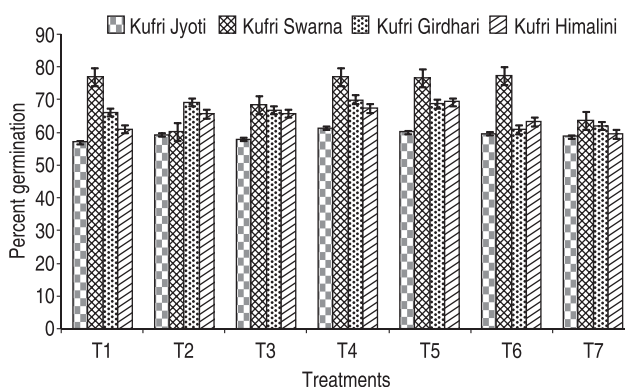


Fig 1 Effect of nitrogen sources on germination of potato cultivars.

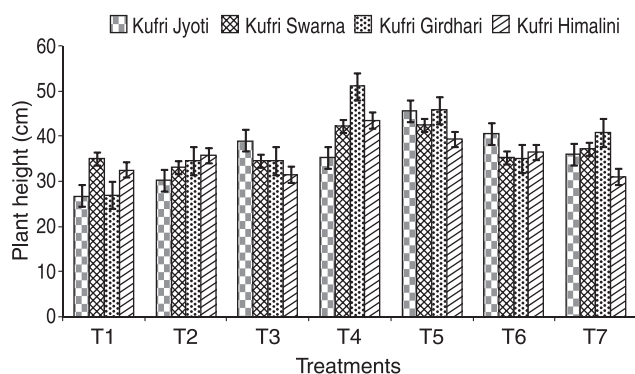


Fig 2 Effect of nitrogen sources on plant height of potato cultivars.

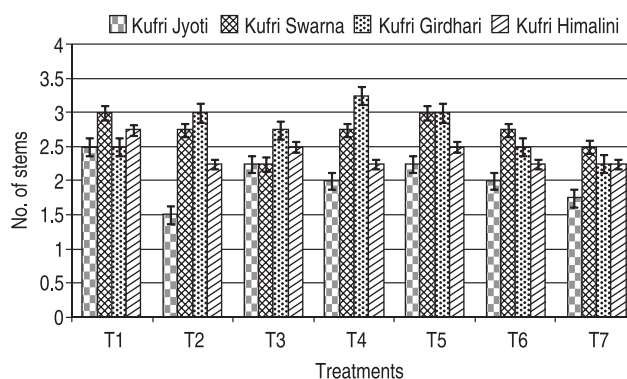


Fig 3 Effect of nitrogen source on number of stems of potato cultivars.

crops, viz. inherent fertility of the soil, growth characters of cultivars and prevailing weather during growing season etc. Nitrogen is essential for maintaining higher haulm growth, increased bulking rate, quality of tuber and more dry matter production. Optimum plant canopy and tuber growth depends on the application of suitable nitrogen sources in soil (Wastermann 2005). Availability of nitrogen to plants varies depending on mineralization and leaching process during the growing season (Rizal *et al.* 2015) which affects vegetative and crop productivity. In our study better plant emergence was noticed in nitrogen supplied in the form of urea than other fertilizer source. The adverse effect of urea application on plant emergence due to liberation of ammonia gas which damages sprout and roots at higher doses under warm dry soil conditions was reported by Singh and Singh (1994). But our result was in contrast to above, this may be due to cooler moist soil condition as the crop season coincides with the rain and planting was done when enough moisture was there in soil. It was also reported that the adverse effect of urea more in alluvial and calcareous soils having high pH as compared to acidic soils (Sharma and Grewel 1987). Hence, our result was also in agreement with the above statement as the soil character of our experimental plot is also acidic with pH of 4.4. The result of our experiment depicted that urea in which nitrogen is in the form of amide produced good vegetative growth than other two sources where nitrogen is in the form of ammonium. In most of the inorganic fertilizers, nitrogen will be in the form of either ammonium-nitrogen or nitrate-nitrogen (Samuel and Ebenezer 2014). The nitrate form of nitrogen was directly absorbed by plant root system. However, nitrogen supplied in the ammonium form is converted to the nitrate form by soil micro-organisms during the growing season through nitrification. Karadogan (1995) indicated that the greatest growth of potato plants resulted by application N as $\text{NO}_3\text{-N}$ followed by $\text{NO}_3 + \text{NH}_4$ and least with $\text{NH}_4\text{-N}$. The chemical composition of urea is unique as it contains neither nitrate-nitrogen nor ammonium nitrogen. Once placed in the soil, soil micro-organisms quickly convert it into ammonium nitrogen and it is therefore, normally considered equivalent to an ammonium source (Osundare 2009). The treatments with urea which shown better result may be due to the easy

mineralization of urea than ammonium sulphate and DAP (Raihanul *et al.* 2002). Nitrogen applied as $\text{CO}(\text{NH}_2)_2$ (urea) in the soil will be converted into $\text{NH}_4\text{-N}$ by enzyme urease to become the N obtainable for plant absorption (Benson and Barnette 1939). In the incubation study Rizal *et al.* (2015) found that urea produced more NH_4^+ in shorter time frame, whereas ammonium sulphate produced more NH_4^+ in longer time frame. Ahmed *et al.* (2009) also demonstrated the predominance of vegetative growth characters of potato plants fertilized with urea over ammonium sulphate. Weak plants with less vegetative growth were reported on application of ammonium sulphate in potato by Dabis *et al.* (1986). The performance of treatments with basal application of ammonium sulphate and DAP found more or less similar in vegetative characters.

Yield parameters

Pooled analysis of variance showed that the marketable, non-marketable and total tuber number as well as yield was significantly influenced by treatments, cultivars and their interactions. In profitable potato cultivation the yield of marketable tubers are of important concern as it determines the profitability of the crop. In the case of marketable tuber number significantly maximum (176.53) was recorded in ammonium sulphate 75% basal + 25% top dressing (T_2). Whereas, nitrogen applied in the form of DAP 75% basal with ammonium sulphate 25% top dressing (T_7) and ammonium sulphate 75% basal + 25% top dressing (T_2) significantly increased the marketable tuber yield (13.85 and 13.23 t/ha). The lowest tuber number (148.47) as well as yield (10.55 t/ha) was noticed in application of urea 75% basal + 25% top dressing (T_5). Among the cultivars, Kufri Girdhari recorded maximum marketable tuber number and yield followed by Kufri Himalini and Kufri Swarna. In the interaction, Kufri Girdhari gave maximum marketable tuber number and yield with treatment T_2 , whereas Kufri Himalini recorded maximum marketable tuber number and yield with treatments T_3 , T_4 and T_7 . Cultivar Kufri Swarna recorded maximum with treatments T_1 and T_3 and Kufri Jyoti with treatments T_2 and T_4 (Table 1).

The maximum non-marketable tuber number was found in nitrogen applied in the form of DAP 75% basal

Table 1 Effect of nitrogen sources on marketable tuber number and yield of potato cultivars

Treatment	Marketable tuber number ('000 nos.)					Marketable tuber yield (t/ha)				
	Kufri Jyoti	Kufri Swarna	Kufri Girdhari	Kufri Himalini	Mean	Kufri Jyoti	Kufri Swarna	Kufri Girdhari	Kufri Himalini	Mean
T ₁	89.72	160.56	222.22	136.67	152.29	6.14	14.20	20.00	11.28	12.91
T ₂	135.84	132.50	300.84	136.94	176.53	8.17	10.36	24.49	9.9	13.23
T ₃	108.34	160.84	204.73	165.28	159.80	8.01	14.32	15.68	12.98	12.75
T ₄	134.17	103.05	270.56	166.95	168.68	9.40	7.29	19.70	11.85	12.06
T ₅	115.83	104.17	220.83	153.05	148.47	6.80	7.78	17.23	10.40	10.55
T ₆	112.78	139.99	238.89	149.17	160.21	7.96	10.82	19.89	10.45	12.28
T ₇	100.56	154.45	255.00	160.00	167.50	7.22	13.61	21.33	13.24	13.85
Mean	113.89	136.51	244.72	152.58		7.67	11.20	19.76	11.44	
Factor	T	V	TV			Factor	T	V	TV	
SEd	2.33	1.73	4.67			SEd	0.18	0.13	0.35	
CD	4.68**	3.54**	9.35**			CD	0.35**	0.27**	0.71**	

T₁ - Basal 100% ammonium sulphate; T₂ - 75% ammonium sulphate as basal + top dressing 25% ammonium sulphate; T₃ - 75% ammonium sulphate as basal + top dressing with 25% urea ; T₄ - 100% urea as basal; T₅ - 75% urea as basal + top dressing with 25% urea ; T₆ - basal (75% DAP+MOP) and top dressing with 25% urea ; T₇ - basal (75% DAP + MOP) + top dressing with 25% ammonium sulphate

+ ammonium sulphate 25% top dressing (T₇), whereas the minimum in ammonium sulphate 100% basal (T₁). Nitrogen applied in the form of DAP 75% basal + urea or ammonium sulphate 25% top dressing (T₆ and T₇) resulted maximum non-marketable tuber yield (2.02 and 1.90 t/ha), whereas nitrogen applied in the form of ammonium sulphate 100% basal (T₁) resulted minimum (1.49 t/ha). Among the cultivars, Kufri Himalini produced more number of non-marketable tuber and yield followed by Kufri Giridhari, Kufri Jyoti. In the interaction Kufri Himalini recorded

more number of non-marketable tuber in T₂ and yield in T₇. Whereas, in Kufri Giridhari ammonium sulphate 75% basal + 25% top dressing (T₂), DAP 75% basal + urea 25% top dressing (T₆), DAP 75% basal + ammonium sulphate 25% top dressing (T₇) and urea 75% basal + 25% top dressing (T₅) resulted more number of non-marketable tuber. Nitrogen applied in the form of ammonium sulphate 75% basal + urea 25% top dressing (T₃) in Kufri Jyoti and DAP 75% basal + urea 25% top dressing (T₆) in Kufri Swarna resulted maximum number of non-marketable tubers. In

Table 2 Effect of nitrogen sources on non-marketable tuber number and yield of potato cultivars

Treatment	Non-marketable tuber ('000 nos.)					Non marketable tuber yield (t/ha)				
	Kufri Jyoti	Kufri Swarna	Kufri Girdhari	Kufri Himalini	Mean	Kufri Jyoti	Kufri Swarna	Kufri Girdhari	Kufri Himalini	Mean
T ₁	76.11	60.28	82.22	74.17	73.19	1.31	1.36	1.89	1.41	1.49
T ₂	85.00	38.89	114.72	166.67	93.82	1.37	1.13	2.17	2.34	1.76
T ₃	88.34	62.22	108.06	127.78	96.60	1.45	0.97	1.97	2.42	1.70
T ₄	76.39	45.56	85.84	123.61	82.85	1.25	1.16	1.73	2.24	1.59
T ₅	85.00	50.84	116.39	110.84	90.76	1.45	1.06	2.39	1.85	1.69
T ₆	83.89	75.00	115.28	120.00	98.54	1.51	1.86	2.51	2.22	2.02
T ₇	80.00	67.22	106.95	159.72	103.47	1.35	1.46	2.15	2.64	1.90
Mean	82.10	57.14	104.21	126.11		1.38	1.29	2.12	2.16	
Factor	T	V	TV			Factor	T	V	TV	
SEd	2.11	1.59	4.22			SEd	0.13	0.09	0.26	
CD	4.23**	3.20**	8.47**			CD	0.26**	0.19**	0.52**	

T₁ - Basal 100% ammonium sulphate; T₂ - 75% ammonium sulphate as basal + top dressing 25% ammonium sulphate; T₃ - 75% ammonium sulphate as basal + top dressing with 25% urea ; T₄ - 100% urea as basal; T₅ - 75% urea as basal + top dressing with 25% urea ; T₆ - basal (75% DAP+MOP) and top dressing with 25% urea ; T₇ - basal (75% DAP + MOP) + top dressing with 25% ammonium sulphate

other cultivars, nitrogen applied in the form of DAP 75% basal + urea 25% top dressing (T_6) recorded maximum yield (Table 2).

The total tuber number as well as yield was found maximum (15.75 t/ha) with application of nitrogen in the form of DAP 75% basal + ammonium sulphate 25% as top dressing (T_7) and it was followed by ammonium sulphate 75% basal + 25% as top dressing (T_2) (14.98 t/ha). The lowest tuber number was observed with ammonium sulphate 100% basal (T_1) and urea 75% basal + 25% top dressing (T_5), whereas the lowest tuber yield (12.24 and 13.65 t/ha) was recorded with nitrogen supplied as urea 75% basal + 25% top dressing (T_5) and 100% basal (T_4). Among the cultivars, Kufri Girdhari recorded maximum tuber number and yield (21.88 t/ha) followed by Kufri Himalini (13.60 t/ha). The lowest tuber yield was recorded in Kufri Jyoti (9.06 t/ha) and tuber number in Kufri Swarna. In the interaction, Kufri Girdhari (26.65 t/ha) recorded significantly maximum tuber number and yield when nitrogen supplied in the form of ammonium sulphate 75% basal + 25% as top dressing (T_2). Whereas, Kufri Himalini (15.88 t/ha) in DAP 75% + ammonium sulphate 25% top dressing (T_7). Kufri Swarna recorded maximum tuber number with ammonium sulphate 75% basal + urea 25% top dressing (T_3) and yield (15.56 t/ha) with ammonium sulphate 100% basal (T_1). Cultivar Kufri Jyoti produced significantly maximum tuber number in T_2 and yield in T_4 (10.65 t/ha) (Table 3).

In contrast to the germination and vegetative growth, we have observed better yield and yield related characters in the treatments where nitrogen was supplied in the form of DAP and ammonium sulphate. Tehran *et al.* (2008) also found ammonium sulphate as the best nitrogenous carrier for potato and urea as inferior source of nitrogen (Sharma

and Grewal 1987). Though nitrate form is easily available to plants compared to ammonium source (Karadogan 1995), Muthoni and Kabira (2011) recorded more tuber yield in di-ammonium phosphate than nitrate source of nitrogen. The total yield given by the treatments with urea was poor even though they gave better vegetative growth. Abd-El Badea *et al.* (2011) also found high marketable tuber yield with ammonium sulphate than urea though good vegetative growth was observed with urea. This may be due to the fact that in the initial days of plant growth nitrogen release from the urea source was more and hence obtained good vegetative growth and less availability during the later stages. Benson and Barnette (1939) reported that the process of 90% conversion of urea by the enzyme urease will happen within 4 days of application at soil temperature of 21°C. Rizal *et al.* (2015) found more NH_4^+ formation in shorter time frame with urea when compare to ammonium sulphate. Studies conducted in potato showed that even though urea is a cheap and concentrated source having 46% N, in potato crop it is 10-15% less efficient than di-ammonium sulphate and calcium ammonium nitrate. The better performance of the ammonium sulphate was attributed to the sulphur supplied by it as it contains 25% sulphur. Sulphur has been rated as the fourth major element after N, P and K for potato and its importance is being recognized in view of its role in improving crop quality and balance of anions (Elmore *et al.* 2010). Muhammad *et al.* (2015) reported that DAP followed by ammonium sulphate was most efficient source of nitrogen than urea in wheat cultivation. Though urea is the most used nitrogen fertilizer, only 20 to 50% is absorbed by crops and the left is lost from the soil system through de-nitrification, volatilization and leaching.

We have also observed differential response among

Table 3 Effect of nitrogen sources on total tuber number and yield of potato cultivars

Treatments	Total tuber number ('000 nos.)					Total tuber yield (t/ha)				
	Kufri Jyoti	Kufri Swarna	Kufri Girdhari	Kufri Himalini	Mean	Kufri Jyoti	Kufri Swarna	Kufri Girdhari	Kufri Himalini	Mean
T_1	165.83	220.83	304.44	210.83	225.49	7.44	15.56	21.89	12.70	14.40
T_2	220.84	171.39	415.56	273.61	270.35	9.54	12.48	26.65	12.24	14.98
T_3	196.67	223.06	312.78	293.05	256.39	9.47	15.28	17.65	15.39	14.45
T_4	210.56	148.61	356.39	290.56	251.53	10.65	8.45	21.40	14.08	13.65
T_5	200.83	155.00	337.22	263.89	239.24	8.23	8.84	19.62	12.24	12.24
T_6	196.67	215.00	354.17	269.17	258.75	9.48	12.67	22.39	12.66	14.30
T_7	180.56	221.66	361.95	319.72	270.97	8.56	15.07	23.47	15.88	15.75
Mean	195.99	193.65	348.93	274.40		9.06	12.48	21.88	13.60	
Factor	T	V	TV			Factor	T	V	TV	
SEd	2.75	2.07	5.50			SEd	0.22	0.017	0.26	
CD	5.51**	4.16**	11.02**			CD	0.45**	0.34**	0.91**	

T_1 - Basal 100% ammonium sulphate; T_2 - 75% ammonium sulphate as basal + top dressing 25% ammonium sulphate; T_3 - 75% ammonium sulphate as basal + top dressing with 25% urea ; T_4 - 100% urea as basal; T_5 - 75% urea as basal + top dressing with 25% urea ; T_6 - basal (75% DAP+MOP) and top dressing with 25% urea ; T_7 - basal (75% DAP + MOP) + top dressing with 25% ammonium sulphate

cultivars and between cultivars and different nitrogen source. The differential response of cultivars reflects the genetic variation between the cultivars as the environmental conditions during growth period were similar. Tehran (2006) reported that potato varieties differ widely among themselves with regard to their nitrogen needs. Studies have shown that the responsiveness of variety to nitrogen application was positively correlated with the duration and genetical class to produce large grade tubers (Swaminathan 1972). Kushwah *et al.* (1990) reported that the response of potato varieties viz. Kufri Lalima, Kufri Sindhuri, Kufri Badshah, Kufri Jyoti and Kufri Chandramukhi to different nitrogen sources were different. Muhammad *et al.* (2015) also reported differential response of different species of wheat with various nitrogen fertilizers. Chien *et al.* (2011) reported ammonium sulphate as best nitrogen fertilizer source which contains free sulphur for increased yield and yield attribute in different crops. Differential response with sorghum and okra cultivars to different nitrogen source was also reported (Amal *et al.* 2007, Ogundare *et al.* 2015).

Conclusion

The farmers' profitability is determined by marketable tuber yield and the same can be achieved by application of nitrogen 90 kg/ha in the form of di-ammonium phosphate 75% as basal + ammonium sulphate 25% top dressing or 75% ammonium sulphate as basal + ammonium sulphate 25% top dressing along with recommended dose of phosphorus and potash as basal.

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