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Seed Quality as Affected by Nitrogen and Potassium During True Potato Seed Production

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Abstract: Three levels of nitrogen (0, 225 and 300 kg N ha^{-1}) and 4 levels of potassium (0, 125, 175 and 225 kg K ha^{-1}) fertilizers were applied to potato mother plants (MF-II) for the production of high quality True Potato Seed (TPS). The effect of N and K application on the quality of TPS was evaluated by nutritional analysis, germination tests in Petri dishes and growth performance in nursery beds. Increase in N application significantly increased N, P, Ca, Mg and Na concentrations in TPS but K did not increase. Increase in K application significantly increased N, P and K concentrations, while decreases in Ca, Mg and Na concentrations in TPS were recorded. TPS that were harvested under different N×K combinations were classified into large-(>1.18 mm) and small sizes-(1.18 to 1.00 mm). Among them, large TPS showed the highest germination rate (97.7%) 12 days after sowing when 300 kg N and 125 kg K ha^{-1} was applied. The coefficient of velocity of germination in large TPS was highest (10.4) when 300 kg N and 125 kg K ha^{-1} were applied. Large TPS also showed high emergence rate (94%), seedling vigor (4.8) and dry matter content (10.5%) in nursery beds when 300 kg N and 125 kg K ha^{-1} was applied. Large TPS always showed better performance than small TPS. In conclusion, the combination of 300 kg N and 125 kg K ha^{-1} was the best combination for application to potato mother plants for the production of high quality TPS.

Key words: Nitrogen, potassium, TPS quality

INTRODUCTION

In a previous report (Roy *et al*., 2007b), we grew potato mother plants (MF-II) with different levels of Nitrogen (N) and Potassium (K) fertilizers (twelve combinations in total) to obtain hybridized True Potato Seed (TPS) with TPS-67 (♂) and investigated the flowering habits of the mother plants and yield components of harvested TPS. The results clearly showed that the combination of 225 kg N and 225 kg K ha^{-1} (hereafter described as N_{225} K_{225}), N_{300} K_{125} and N_{225} K_{125} resulted in the highest yield of berries $plant^{-1}$ (207.2 g $plant^{-1}$), highest 100-TPS weight (83.8 mg) and highest TPS yield (145.3 kg ha^{-1}), respectively. By considering all the above described results together, we concluded that N_{300} K_{125} was the best combination for the commercial production of TPS that were obtained from the hybrid of MF-II×TPS-67 when the production was focused on the yield and size of TPS.

However, for the production of TPS, seed quality, which is commonly evaluated as high germination rate, uniform germination property and vigorous seedling growth after germination, is also a crucial element (Upadhya *et al*., 2003; Islam *et al*., 2000; Pallais, 1987; Dickson, 1980; McDonald, 1980).

Kanzikwera *et al*. (2000) demonstrated that the combination of N_{240} $K_{265.6}$ resulted in low germination rate and less seedling vigor compared with N_{240} $K_{132.8}$. Thus, the quality of TPS also varies significantly according to the different combinations of N and K fertilizers applied to the mother plants (Roy *et al*., 2007b; Pallais *et al*., 1984), mainly due to the different nutrient levels that are contained in the harvested TPS.

Wheat seeds containing high N germinate faster and develop into larger seedlings than those containing normal N (Lopez and Grabe, 1973). In lettuce, a linear relationship was found between N concentration in the seed and seedling vigor after germination (Soffer and Smith, 1974). On the other hand, a negative correlation was found between K concentration and germination rate in primrose (*Primula vulgaris* H.) seed (Zerche, 2005).

In addition to the importance of nutrient levels in TPS, the size of TPS also affects germination and subsequent seedling growth. Almekinders and Wiersema

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(1991) found that large TPS showed better germination and earlier emergence than small TPS. When small TPS take a long time to emerge after sowing, subsequent crop production will be greatly diminished by soil related problems such as fast-growing weeds and pathogens.

The objective of this study was to assess the effect of N and K application to potato mother plants (MF-II) on the growth performance of harvested TPS.

MATERIALS AND METHODS

Planting materials and cultivation method: Seed tubers of two desired parental lines (MF-II and TPS-67 as female and male lines, respectively) were grown during 2005 to 2006 in the field of the Tuber Crops Research Center, Bangladesh to make hybridized TPS. Farm yard manure which contains approximately 1.0 to 1.2% N was applied (10 t ha^{-1}) in the experimental plots one week before (14 October 2005) the planting of the seed tubers. On 18 October, chemical fertilizers which contain P-Gypsum-Zinc sulphate-Borax at 120-120-12-6 kg ha^{-1} were applied in the experimental plots. Effect of N×K fertilizers on the quality of TPS was investigated by applying 12 different N×K combinations of 3 levels of nitrogen (N_0, N_{225} and N_{300} kg ha^{-1} as total amount of application) and 4 levels of potassium (K_0, K_{125}, K_{175} and K_{225} kg ha^{-1} as total amount of application) for the production of the female plants. The entire quantity of K (K_{0-225}) was applied 3 days before planting of the seed tubers (18 October) because it is slowly absorbed into the plants, while only one-third of entire quantity of N (0, 75 and 100 kg ha^{-1} for N_0, N_{225} and N_{300}) was applied on 18 October as a basal dressing, irrespective of total amount of N×K application. On 21 October 2005, seed tubers were planted in a split-plot design with 3 replicates. The rest amount of N fertilizer was equally applied in 4 installments (0, 37.5 and 50 kg ha^{-1} for N_0, N_{225} and N_{300}) at 10 day intervals starting from 30 Days after Planting (DAP) (21 November, 1, 11 and 21 December). Splitting of N application in 4 equal amounts helped in reducing the loss of excessive N fertilizer applied at planting and better utilization of the fertilizer particularly during rapid growth of plants, flowering, berry setting and development of seeds (Phillips *et al.*, 2004; Pallais *et al.*, 1987). The procedure of fertilizer's application was the same as described in our previous reports (Roy *et al.*, 2007a, b). For the production of male plants, seed tubers were planted in separate plots on 14 November. A standard commercial amount of N×K combination (N_{150} K_{125}) was applied as basal dressing (Roy *et al.*, 2005). On 30 November (39 DAP), flowering of the female plants was started and they were hand pollinated with the previously collected pollen grains of the male plants. The crossing between the two parental lines and the subsequent production of TPS were the same as described previously (Roy *et al.*, 2007a). Berries were harvested during 12 to 17 January 2006 (42 to 47 days after pollination). TPS that were produced from the 12 different fertilizer combinations were stored in a desiccator for approximately 5 months at room temperature.

Determination of N level in TPS: Dried TPS samples were homogenized in a mortar and approximately 0.5 g powder was transferred to a 100 mL flask. Approximately 1.1 g digestion mixture (1.0 g Na_2SO_4 + 100 mg mercuric oxide) and 5 mL concentrated H_2SO_4 were added to the sample and then heated to 160°C for 3 to 4 h in a digestion chamber until the sample was digested completely. The flask was then cooled in tap water and brought up to 100 mL with distilled water. A 10 mL sample of the solution was put into a Micro-Kjeldahl distillation tube with 5 mL 50% NaOH and 2.5 mL 15% $Na_2S_2O_3$ and the solution was distilled with steam for 10 min. A 15 mL sample of the distillate was decanted into a test tube with 25 mL of 2% boric acid solution, 4 to 6 drops of 0.2% methyl red and methylene blue as an indicator. The solution was then titrated against 0.02% N HCl. In each analysis, water was also digested and distilled as a blank. The concentration of N in TPS was determined by the method of Ma and Zuazaga (1942).

Determination of P, K, Ca, Mg and Na: TPS samples (approximately 50 mg) from each treatment were digested with 2 mL 16 N HNO_3 overnight at room temperature. Two milliliters of 60% $HClO_4$ was added and then the solution was successively heated to 80°C for 30 min, 120°C for 30 min and 160°C for 90 min. The digested solutions were then cooled to room temperature, filtered through a glass fiber filter (25 µm in diameter) and brought up to 25 mL with distilled water. Phosphorus, K, Ca, Mg and Na concentrations in each sample were determined using an Inductively Coupled Plasma (ICP) spectrophotometer (model Liberty 220, Varian, Victoria, Australia).

Seed quality tests *in vitro*: TPS that were produced from each combination of N×K were classified into large- (>1.18 mm) or small- (1.00 to 1.18 mm) seed. TPS were then soaked in 0.15% Gibberellic Acid (GA_3) solution at room temperature for 24 h, one hundred seeds per each size class were sown in Petri dishes (15 cm diameter) equipped with wet filter paper (Whatman No. 1, Middlesex, UK) and then incubated at 20°C for 12 days. The seeds were watered as necessary. The germination rate of TPS was recorded at 6, 9 and 12 Days After Sowing (DAS). Coefficient of velocity (CoV) of germination was also calculated as follows (Scott and Williams, 1984):

$$CoV = 100[\Sigma N_i / \Sigma N_i\ T_i]$$

Where:
N = No. of seeds germinated on day
i and T = No. of days after sowing

The experiment was conducted in a completely randomized design with 3 replicates.

Seed quality tests *in vivo*: Seed quality *in vivo* was determined according to the growth performance of the seedling. The experiment was conducted following a split-plot design with 3 replicates in a nursery bed of Sher-e-Bangla Agricultural University during 2006-2007. Soil substrates of the nursery bed were soil, sand and farmyard manure (1:1:1 v/v). The unit plot size was 1 m^2. TPS that were harvested under different N×K combinations were sown and grown as described previously (Roy *et al*., 2005) and the percentage of emerged shoots at 10, 15 and 20 DAS and CoV were recorded.

Seedling vigor was visually evaluated at 21 DAS using five staged scales i.e., 1 = small seedlings with stunted growth, 2 = moderate growth but visually stunted, 3 = good growth, 4 = vigorous, tall plants with green foliage and 5 = transplantable seeding with vigorous, green, strong stem. At 30 DAS, the seedlings were cut at the soil surface, weighed, oven-dried at 70°C for 72 h and re-weighed.

Statistical analysis: Analysis of variance was performed according to MSTAT-C statistical software (MSTAT-C, 1991). Means were compared using the Least Significant Differences (LSDs) test at a 5% probability level.

RESULTS

Nutrient concentration in TPS as affected by different combination of N and K fertilizers: Nitrogen, P, K, Ca, Mg and Na concentrations were significantly ($p \le 0.01$) influenced by different levels of N application. All ions except K showed the highest level when N_{300} was applied (Table 1). On the other hand, N, P and Mg concentrations decreased with increasing K application.

The combined effect of N×K on the nutrient concentration was also significant, except for Ca and Mg (Table 1, 2). The highest values of N, P, K and Na concentrations were obtained when N_{300} K_{125}, N_{225} K_{125}, N_{225} K_{175} and N_{225} K_0 (45.4, 11.4, 8.0 and 2.1 mg g^{-1} dry weight) were applied, respectively.

Effect of N×K and TPS size on germination rate and CoV of germination: When N was not applied (N_0), germination of both large and small TPS was strongly inhibited, irrespective of K application level throughout the experimental period (Table 3). However, germination rate of TPS changed largely by different K applications even if N was applied together with K; i.e., large TPS showed the highest germination rate (43.0-45.3%) at 6 DAS when $N_{225\text{-}300}$ K_{125} was applied, but were largely inhibited (8.6-9.0%) when K_{225} was applied (Table 3). Among the small TPS samples the highest germination rate (23.7-18.3%) at 6 DAS was when $N_{225\text{-}300}$ K_{125} was applied, but the rate was less than half of the rate of large TPS and this lower germination rate of small TPS did not recover even at 12 DAS (Table 3).

The combination of $N_{225\text{-}300}$ K_{125} also resulted in the highest CoV of germination (10.3-10.4), irrespective of TPS size (Table 3).

Performance of TPS in nursery beds

Percentage of emerged seedlings: The percentage of emerged seedlings in the nursery beds was significantly influenced by the N×K combination and TPS size

Table 1: Single effect of different levels of nitrogen (N) or potassium (K) fertilizers supplied to the potato mother plant on nutrient concentrations in the harvested TPS

Application ($kg\ ha^{-1}$)	Nutrient concentration in TPS ($mg\ g^{-1}$ dry weight) N	P	K	Ca	Mg	Na
N_0	37.1^c	8.2^b	5.9^b	2.6^c	3.9^c	1.6^b
N_{225}	42.4^b	10.2^a	7.2^a	3.7^b	4.4^b	1.7^a
N_{300}	43.4^a	10.0^a	6.0^b	3.8^a	4.5^a	1.7^a
K_0	41.1^b	9.5^b	5.8^b	3.5	4.6^a	1.8^a
K_{125}	43.1^a	10.2^a	6.5^a	3.4	4.4^b	1.6^b
K_{175}	40.8^b	9.5^b	6.7^a	3.3	4.1^b	1.6^b
K_{225}	38.9^c	8.8^c	6.5^a	3.3	4.0^c	1.6^b
Significance						
N	**	**	*	**	**	**
K	**	**	**	ns[z]	**	**
N×K	*	**	**	ns	ns	*

N_0 to N_{300} and K_0 to K_{225} indicate that nitrogen and potassium were applied at 0 to 300 kg ha^{-1} and 0 to 225 kg ha^{-1}, respectively. *,**: Significant at $p \le 0.05$ and 0.01, respectively. Different letter(s) within each column indicate significant differences by LSD test at $p \le 0.05$. [z]ns: Non-significant

Table 2: Combined effect of different levels of N×K fertilizer supplied to the potato mother plants on N, P, K, Ca, Mg and Na concentrations in the harvested TPS

Fertilizer (N×K)	Nutrient concentration in TPS ($mg\ g^{-1}$ dry weight) N	P	K	Ca	Mg	Na
$N_0 K_0$	37.80	8.40	5.60	2.6	4.4	1.50
$N_0 K_{125}$	39.50	8.40	5.80	2.5	3.9	1.50
$N_0 K_{175}$	37.80	8.10	6.10	2.5	3.6	1.60
$N_0 K_{225}$	33.30	8.00	6.20	2.8	3.7	1.70
$N_{225} K_0$	42.40	9.10	5.70	3.8	4.7	2.10
$N_{225} K_{125}$	44.00	11.40	6.90	3.7	4.5	1.80
$N_{225} K_{175}$	41.80	10.60	8.00	3.6	4.2	1.60
$N_{225} K_{225}$	41.30	9.60	7.20	3.6	4.1	1.70
$N_{300} K_0$	43.00	11.00	6.10	4.0	4.8	1.60
$N_{300} K_{125}$	45.40	10.70	5.80	3.9	4.7	1.70
$N_{300} K_{175}$	42.40	9.40	6.10	3.7	4.4	1.30
$N_{300} K_{225}$	41.90	8.90	6.10	3.6	4.2	1.40
Mean	41.00	9.50	6.40	3.4	4.3	1.60
LSD (0.05)[z]	3.14	0.46	0.52	ns[y]	ns	0.26

[z]: LSD ($p \le 0.05$) for comparing means in columns, [y]: ns = Non-significant

(Table 4). The rate decreased with increasing K application levels, irrespective of N level or TPS size. Large TPS emerged at rates higher than 90% when N_{225} K_{125} or $N_{300}K_{125}$ was applied (Table 4).

CoV of emergence: Coefficient of velocity of emergence was significantly influenced by the N×K combination and TPS size. High CoV of emergence was found in large TPS when N_{300} K_{125}, $N_{300}K_{175}$ or $N_{225}K_{125}$ was applied (6.73, 6.65 and 6.64, respectively) (Table 4).

Seedling vigor: Seedling vigor was also significantly influenced by the N×K combination and TPS size. Among the 12 treatment combinations, large seeds showed the best performance (4.8) compared with all other treatments (less than 4.3) when $N_{300}K_{125}$ was applied (Table 4).

Seedling weight: Fresh and dry weight of the seedlings was also significantly influenced by the N×K combination and TPS size. Large seeds resulted in the maximum fresh and dry seedling weight when N_{300} K_{125}, N_{300} K_{175}, or N_{225} K_{125} were applied (6.4 and 0.68 g, 6.23 and 0.64 g and 6.13 and 0.63 g, respectively) (Table 4).

The highest percentage of dry matter was found in seedlings grown from large seeds when N_{300} K_{125} was applied; whereas, the lowest was found in seedlings grown from small seeds when N_0 K_{225} was applied (10.5 and 7.8%, respectively) (Table 4).

Table 3: Combined effect of different levels of N×K fertilizer supplied to the potato mother plants on the percentage of germination at 6, 9 and 12 DAS and CoV of germination of harvested TPS sown in Petri dishes

Fertilizer combination×seed size[z]	Germination (%) 6 DAS	9 DAS	12 DAS	CoV of germination
N_0K_0×Large	2.70	16.10	44.00	9.10
N_0K_0×Small	0.00	9.30	37.60	8.80
N_0K_{125}×Large	7.00	34.60	72.00	9.30
N_0K_{125}×Small	1.30	14.00	59.30	8.80
N_0K_{175}×Large	4.30	27.30	67.00	9.20
N_0K_{175}×Small	1.00	12.00	49.70	8.80
N_0K_{225}×Large	3.00	20.00	62.70	9.00
N_0K_{225}×Small	0.30	13.70	49.30	8.80
$N_{225}K_0$×Large	18.70	58.00	72.30	9.90
$N_{225}K_0$×Small	11.30	42.30	60.00	9.70
$N_{225}K_{125}$×Large	43.00	89.60	95.70	10.30
$N_{225}K_{125}$×Small	23.70	70.70	81.00	10.00
$N_{225}K_{175}$×Large	37.00	87.00	90.70	10.20
$N_{225}K_{175}$×Small	16.00	62.30	77.30	9.80
$N_{225}K_{225}$×Large	8.60	40.30	72.30	9.50
$N_{225}K_{225}$×Small	8.00	23.70	55.30	9.40
$N_{300}K_0$×Large	21.00	57.00	75.70	9.90
$N_{300}K_0$×Small	12.00	40.00	61.30	9.70
$N_{300}K_{125}$×Large	45.30	94.70	97.70	10.40
$N_{300}K_{125}$×Small	18.30	68.30	80.30	` 9.90
$N_{300}K_{175}$×Large	36.00	86.00	89.70	10.20
$N_{300}K_{175}$×Small	15.30	60.60	80.00	9.80
$N_{300}K_{225}$×Large	9.00	20.00	55.70	9.40
$N_{300}K_{225}$×Small	7.00	13.00	38.70	9.40
CV (%)	12.41	6.34	3.93	0.85
LSD (0.05)[y]	2.97	4.58	4.37	0.14

[z]: TPS were classified into large and small sizes (>1.18 mm and 1.00-1.18 mm, respectively). [y]: LSD ($p \leq 0.05$) for comparing means in columns

Table 4: Combined effect of different levels of N×K fertilizer supplied to the potato mother plants on the percentage of emerged seedlings at 10, 15 and 20 DAS, CoV of emergence, seedling vigor, seedling fresh wt., seedling dry wt. and percentage of dry matter of harvested TPS grown in nursery beds

Fertilizer combination×seed size[z]	Emergence (%) 10 DAS	15 DAS	20 DAS	CoV of emergence	Seedling Vigor	Seedling wt. (g) Fresh	Dry	Dry matter (%)
N_0K_0×Large	70.00	74.30	79.30	6.58	2.70	4.70	0.45	9.50
N_0K_0×Small	30.00	39.70	50.00	6.32	2.10	3.10	0.29	9.20
N_0K_{125}×Large	76.30	81.00	84.00	6.60	2.90	5.10	0.47	9.20
N_0K_{125}×Small	47.00	61.00	67.70	6.42	2.50	3.30	0.30	9.00
N_0K_{175}×Large	68.00	72.00	78.00	6.57	2.60	4.63	0.42	9.00
N_0K_{175}×Small	16.30	30.00	59.30	5.87	1.90	3.20	0.28	8.70
N_0K_{225}×Large	62.00	67.30	66.70	6.62	2.20	4.01	0.38	8.70
N_0K_{225}×Small	12.00	37.00	57.30	5.80	1.70	3.23	0.27	7.80
$N_{225}K_0$×Large	77.30	83.30	86.00	6.60	3.70	5.67	0.56	10.00
$N_{225}K_0$×Small	50.30	60.30	68.70	6.45	3.30	4.10	0.37	9.40
$N_{225}K_{125}$×Large	90.70	92.30	94.30	6.64	4.10	6.13	0.63	10.30
$N_{225}K_{125}$×Small	53.30	78.70	88.30	6.33	3.50	4.83	0.48	9.90
$N_{225}K_{175}$×Large	73.00	78.00	82.00	6.58	3.30	5.83	0.60	10.20
$N_{225}K_{175}$×Small	50.00	71.70	81.30	6.34	2.50	4.87	0.47	9.60
$N_{225}K_{225}$×Large	68.00	73.00	75.30	6.60	3.00	5.87	0.58	9.80
$N_{225}K_{225}$×Small	30.30	45.00	58.00	6.24	2.00	4.43	0.42	9.50
$N_{300}K_0$×Large	83.00	88.70	89.30	6.71	4.30	4.93	0.51	10.30
$N_{300}K_0$×Small	47.30	57.00	66.70	6.42	3.50	4.01	0.41	10.10
$N_{300}K_{125}$×Large	90.30	92.30	94.00	6.73	4.80	6.40	0.68	10.50
$N_{300}K_{125}$×Small	52.00	80.00	87.00	6.33	3.60	4.39	0.44	9.90
$N_{300}K_{175}$×Large	79.70	81.00	83.00	6.65	3.60	6.23	0.64	10.20
$N_{300}K_{175}$×Small	44.70	61.70	62.00	6.45	2.70	4.09	0.39	9.40
$N_{300}K_{225}$×Large	65.00	73.30	75.00	6.57	2.60	5.97	0.60	10.00
$N_{300}K_{225}$×Small	25.00	47.00	53.00	6.20	1.70	4.03	0.35	8.70
CV (%)	5.23	11.39	4.58	0.97	5.79	4.58	3.52	2.77
LSD (0.05)[y]	5.00	13.01	5.69	0.10	0.29	0.36	0.05	0.45

[z]: TPS were classified into large and small sizes (>1.18 mm and 1.00-1.18 mm, respectively), [y]: LSD (p = 0.05) for comparing means in columns

DISCUSSION

The concentration of nutrients in TPS was influenced by different levels of N and K fertilizers supplied to the mother plants. Nitrogen level in TPS increased as the N fertilizer level increased and just reverse when K fertilizer level increased. Such a negative interaction between N and K application has also been reported in other seed potato plants (Bester and Maree, 1990).

Different levels of N and K fertilizers supplied to the mother plants also affected the accumulation of other cations in TPS. Potassium application at a high (225 kg ha^{-1}) level resulted in decreases in P, Mg and Na concentrations in TPS, while N application resulted in increases the same (Table 1). Similar negative interactions between N and K fertilizers on cation concentrations in the harvested seeds were also reported in corn (Karien *et al*., 1987) and wheat (Karien and Whitney, 1980). The negative influence of K application on the accumulation of other cations such as Mg and Na (Table 1) also suggests K-Mg and K-Na antagonism as reported by Marschner (1990). A positive correlation between N application and P and Ca concentrations in TPS was found (Table 1) as reported by Karien and Whitney (1980) in wheat. In our experiment, TPS with high N, P and Ca concentrations also showed the highest emergence rate and seedling vigor (Table 4) as reported in tobacco (Thomas and Raper, 1979).

Seed quality, which is shown as high germination rate and high seedling vigor, often correlates with the protein concentration in the seeds (Bhatt *et al*., 1989). These authors further observed that the TPS with high protein concentration germinated faster and developed into larger seedlings. Although the protein concentration in TPS was not measured in our experiment, the protein concentration in seeds correlates well with nitrogen concentration and it can be roughly calculated by multiplying the percentage of N by 6.25 (Ma and Zuazaga, 1942). In this aspect, TPS with a high N concentration in our experiment also contained high amounts of protein and showed better seedling performance (Table 4). On the contrary, high rates of K application reduced N concentration in TPS (Table 1) suggesting that excess K application may inhibit protein synthesis in TPS through interference with N uptake and reduced the growth performance after germination as Karien *et al*. (1987) reported in corn.

Although the germination rate of TPS *in vitro* was always higher than the emergence rate of the seedling *in vivo* as Gallagher and Nabi (1984) reported previously in TPS, the combination effect of N×K on the germination and emergence rates and their CoV were apparent both *in vitro* and *in vivo*. The highest emergence rate of TPS was always obtained when N_{300} K_{125} or N_{225} K_{125} were applied (data not presented), while the rate became lower as K application increased. Kanzikwera *et al*. (2001, 2000) also found a similar effect of N and K combination on the emergence rate of TPS.

A high CoV indicates that more seeds germinated or more seedlings emerged over a shorter time (Scott and Williams, 1984). In our experiment, both CoV of germination and emergence were always higher as N application increased, while they became lower as K application increased, indicating that N is a key factor for obtaining high CoV. In brinjal and soybean seeds, nitrogen application higher than those required levels for optimal crop production has been recognized to improve the seedling vigor (Naik *et al*., 1996; Van *et al*., 1982; Gray and Thomas, 1982; Delouche, 1980). In tomato and tobacco, increased N application to the mother plants increased the seed germination rate and enhanced germination uniformity (Seno *et al*., 1987; Thomas and Raper, 1979).

In this study, large TPS always performed better in all aspects than small TPS (Table 3, 4). Bhatt *et al*. (1989) reported that TPS size was associated with the quality because large seeds contained higher level of protein than small ones and they germinated faster and had the highest percentage of germination. In our experiment, large TPS that were produced under N_{300} K_{125} showed faster emergence and better seedling growth (Table 4). Lopez and Grabe (1973) also reported that the application of high N to wheat plants increased N concentration in the seeds. In addition, seeds with high N concentration germinated faster and developed into larger seedlings with higher dry matter content.

Although the percentage of emergence of TPS at 20 DAS differed little in both large and small TPS especially when N_{225} K_{125}, N_{225} K_{175} or N_{300} K_{125} were applied, plant size at 30 DAS was significantly greater in large TPS than in small TPS (Table 4), because small TPS with low N concentration emerged slower and also performed less well in terms of seedling vigor than large TPS as reported by Malagamba (1988) in TPS. Baki (1980) also showed that N in soybean seed was important during seedling growth.

As a conclusion, present results show that application of $N_{225\text{-}300}K_{125\text{-}175}$ to potato mother plants could improve TPS harvest quality when the quality was evaluated as growth performance both *in vitro* and *in vivo*. The range of this N×K combination was within the range of the best combination ($N_{225}K_{125}$) for obtaining the highest TPS yield from the crossing of MF-II and TPS-67 (Roy *et al*., 2007b). However, less seedling vigor under N_{225} K_{125} as compared with N_{300} K_{125} (Table 4) suggests that the application of N at 225 kg ha^{-1} will be too low for obtaining high quality TPS. This is also confirmed from the view point of harvesting large TPS, where the application of N at 300 kg ha^{-1} was required (Roy *et al.*, 2007b). Therefore, we conclude that 300 kg N and 125 kg K ha^{-1} is the best combination for obtaining not only large TPS (Roy *et al.*, 2007b), but also preferable growth performance of the seedlings.

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