ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 6 (1): 88-93, 2007
ISSN 1812-5379

Flower, Berry and True Potato Seed Production in Potato Mother Plants (*Solanum tuberosum* L.). 2. Effects of Nitrogen and Potassium Fertilizers

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Abstract: The combined effects of different levels of nitrogen and potassium fertilizers on flowering and yield components of True Potato Seed (TPS) were investigated using crosses of ♀MF-II and ♂TPS-67. Twelve combinations of 3 N (0, 225 and 300 kg ha^{-1}, respectively) and 4 K (0, 125, 175 and 225 kg ha^{-1}, respectively) levels were applied to MF-II. Different levels of N or K showed significant effects on flowering and TPS yield. The combinations of N and K were also significant for most of the parameters except for the number of flowers inflorescence^{-1}, number of berries plant^{-1} and number of TPS per small and medium size berry. Out of 12 treatment combinations, 225 kg N and 225 kg K ha^{-1} produced the highest number of berries (22.7) and yield of berries plant^{-1} (207.2 g), whereas 225 kg N and 125 kg K ha^{-1} produced the maximum number of TPS berry^{-1} (196). The weight of 100-TPS increased with increasing N rate but decreased with increasing K rate; the results revealed that an inverse relation was observed between N and K on 100-TPS weight. The highest 100-TPS weight (83.8 mg) and maximum quantity (113.0 kg ha^{-1}) of quality (> 1.18 mm) TPS were obtained with the application of 300 kg N and 125 kg K ha^{-1}, while 225 kg N and 125 kg K ha^{-1} produced the highest TPS yield (145.3 kg ha^{-1}). Our study showed that 300 kg N and 125 kg K ha^{-1} was the best combination for commercial production of quality TPS obtained from MF-II x TPS-67.

Key words: Berry, nitrogen, potassium, TPS weight, yield

INTRODUCTION

Although potato production using True Potato Seed (TPS) is becoming popular in many areas of the world, especially in developing countries, how to obtain quality seeds from female potato plants has remained a problem which urgently needs to be solved (Upadhya *et al.*, 2003; Islam *et al.*, 2000; Pallais, 1991, 1987). The production of quality seed is strongly influenced by fertilizers. Among them, N, P, K and their combinations are the most important for improving not only the quality but also the yield of TPS (Kanzikwera *et al.*, 2000; Upadhya *et al.*, 1984).

Nitrogen applications higher than 225 kg ha^{-1} have been reported to increase flower production, pollen germination, berry setting and 100-TPS weight (Roy *et al.*, 2006; Pallais *et al.*, 1987, 1984). An increase in N supply enhances the export of cytokinins from the roots to the shoots, resulting in delayed senescence of the plants. Thus, berries have a longer period to mature on the mother plants and a better chance for high quality seed production (Pallais, 1987; Van *et al.*, 1982).

Application of P up to a certain amount also positively correlates with flowering, berry setting, seed weight and TPS production (Upadhya *et al.*, 1984). In a previous study (Roy *et al.*, 2006), we showed that the application of 120-180 kg P ha^{-1} produced the highest 100-TPS weight and TPS yield.

The effects of K, however, are different from those of N and P. With a high rate (>132.8 kg ha^{-1}) of K application, the TPS mother plant shows a negative response of 100-TPS weight and poor response of TPS production (Kanzikwera *et al.*, 2000).

The effects of combinations of N, P and/or K are more complicated and have been less studied comparing with the effects of the single applications. In a previous study (Roy *et al.*, 2006), we demonstrated that the optimum dosages of N and P combinations to obtain the highest 100-TPS weight and TPS yield were different, i.e., the combination of 300 kg N and 120 kg P ha^{-1} and 225 kg N and 120 kg P ha^{-1} produced the highest 100-TPS weight and TPS yield, respectively, of MF-II, which was the most promising female parent in Bangladesh (Roy *et al.*, 2005; Moniruzzaman, 2000). Upadhya *et al.*

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(1984) showed that application of 240 kg N and 140 kg P ha^{-1} produced the highest TPS yield. The combinations of 240 kg N and 132.8-265.6 kg K ha^{-1} depressed 100-TPS weight, indicating a negative interaction between the two nutrients (Kanzikwera *et al*., 2000).

In this study, therefore, we examined the effects of combinations of N and K at the optimum dosage for P application (120 kg ha^{-1}) (Roy *et al*., 2006) and tried to find the best combinations of N, P and K application for the production of hybrid TPS from MF-II x TPS-67.

MATERIALS AND METHODS

The experiment was conducted at the experimental field of the Tuber Crops Research Center, Bangladesh Agricultural Research Institute, Joydevpur, Bangladesh, during 2005-2006. The soil had a pH of 6.82 (Jackson, 1962) and contained 1.63% organic matter (Pase *et al*., 1982), 0.095% N (Jones, 1991), 0.0011% available P (Olsen *et al*., 1984), 0.133 me% exchangeable K (Black, 1965) and 0.00126% available S content (Page *et al*., 1982).

Considering the findings of our previous study, 2 levels of N (225 and 300 kg ha^{-1}) and a fixed value of P (120 kg ha^{-1}) were selected for testing as promising for TPS production. In this experiment, therefore, factor 1 comprising 3 levels of N: 0, 225 and 300 kg ha^{-1} (N_0, N_{225} and N_{300} kg ha^{-1}, respectively) and factor 2 comprising 4 levels of K: 0, 125, 175 and 225 kg ha^{-1} (K_0, K_{125}, K_{175} and K_{225} kg ha^{-1}, respectively) were applied in a split-plot design with 3 replications. Nitrogen was assigned to main-plots and K to sub-plots. Urea, muriate of potash and triple super phosphate were the N, K and P sources. The mother plants were planted on 21 October 2005 and received the recommended rates of fertilizers for tuber production of 120-12-6 kg ha^{-1} Gypsum-$ZnSO_4$-Borax and 10 t ha^{-1} farmyard manure, at 3 days before planting (Anonymous, 2004). Based on our previous findings, 120 kg P ha^{-1} was applied in all treatments (Roy *et al*., 2006). Male plants (TPS-67) were planted in separate plots on 14 October 2005 to harmonize their flowering with that of the female plants. All other practices and procedures of production, extraction and drying of TPS were similar to those described in our previous report (Roy *et al*., 2006).

After proper drying, TPS were separated into fractions of large-(> 1.4 mm), medium-(1.4-1.18 mm) and small-(<1.18 mm) sized seed, using testing sieves (Tokyo Screen, Japan).

The analysis of variance was carried out using MSTAT-C statistical software (MSTAT-C, 1991). Means were compared using the least significant differences (LSDs) test at a 5% probability level.

RESULTS

Effects of N and/or K on flowering: Nitrogen showed significant effects ($p \leq 0.01$) on the number of inflorescences $plant^{-1}$ (NIPP) and number of flowers $inflorescence^{-1}$ (NFPI), both of which increased with increasing N rates (Table 1). Although K also showed significant effects ($p \leq 0.01$) on these parameters, $K_{175\text{-}225}$ showed similar effects. The combined effect of N and K on NIPP was also significant (p = 0.05), but that on NFPI was not significant.

A tendency of gradual increases in NIPP and NFPI with increasing rates of N and K was also observed (Fig. 1A and B). Application of $N_{300}K_{225}$ produced the maximum NIPP (9.7) and $N_{300}K_{175}$ and $N_{300}K_{125}$ had similar effects (9.2 and 8.4, respectively) (Fig. 1A). The maximum NFPI was found at $N_{300}K_{225}$ (22.1) (Fig. 1B).

Effect of N and/or K on the number of berries $plant^{-1}$, mean berry weight and yield of berries: Different levels of

Table 1: Effect of nitrogen, potassium and nitrogen x potassium on sexual reproductive characters in MF-II x TPS-67

Application (kg ha^{-1})	NIPP	NFPI[x]	No. of berries $plant^{-1}$	Mean berry wt. (g)	Yield of berry (g $plant^{-1}$)	No. of TPS $berry^{-1}$	Wt. of 100-TPS (mg)	Yield of TPS (kg ha^{-1})
N_0	5.1c	14.5c	16.8c	5.6c	94.1c	146b	60.3c	49.5c
N_{225}	6.5b	16.8b	21.3a	8.2a	175.7a	178a	77.2b	123.6a
N_{300}	8.1a	18.7a	20.1b	7.6b	156.5b	172a	79.4a	114.2b
K_0	4.6c	12.8c	16.9c	5.6c	94.6d	143d	68.1d	61.9b
K_{125}	6.7b	16.5b	19.2b	7.5b	148.0c	180a	75.6a	108.4a
K_{175}	7.3a	18.1a	20.2ab	7.6ab	157.1b	171b	73.7b	107.5a
K_{225}	7.7a	19.3a	21.2a	7.8a	168.7a	167c	72.1c	105.4a
Significance								
N	**	**	**	**	**	**	**	**
K	**	**	**	**	**	**	**	**
N x K	*	ns[y]	ns	**	*	*	*	**

NIPP = Number of inflorescences $plant^{-1}$, NFPI = Number of open flowers $inflorescence^{-1}$ and [x]values are the mean of the 1st and 2nd inflorescences; *, **Significant at $p \leq 0.05$ and 0.01, respectively. Different letter(s) within columns indicate a significant difference by LSD test at $p \leq 0.05$; [y] ns: Non-significant

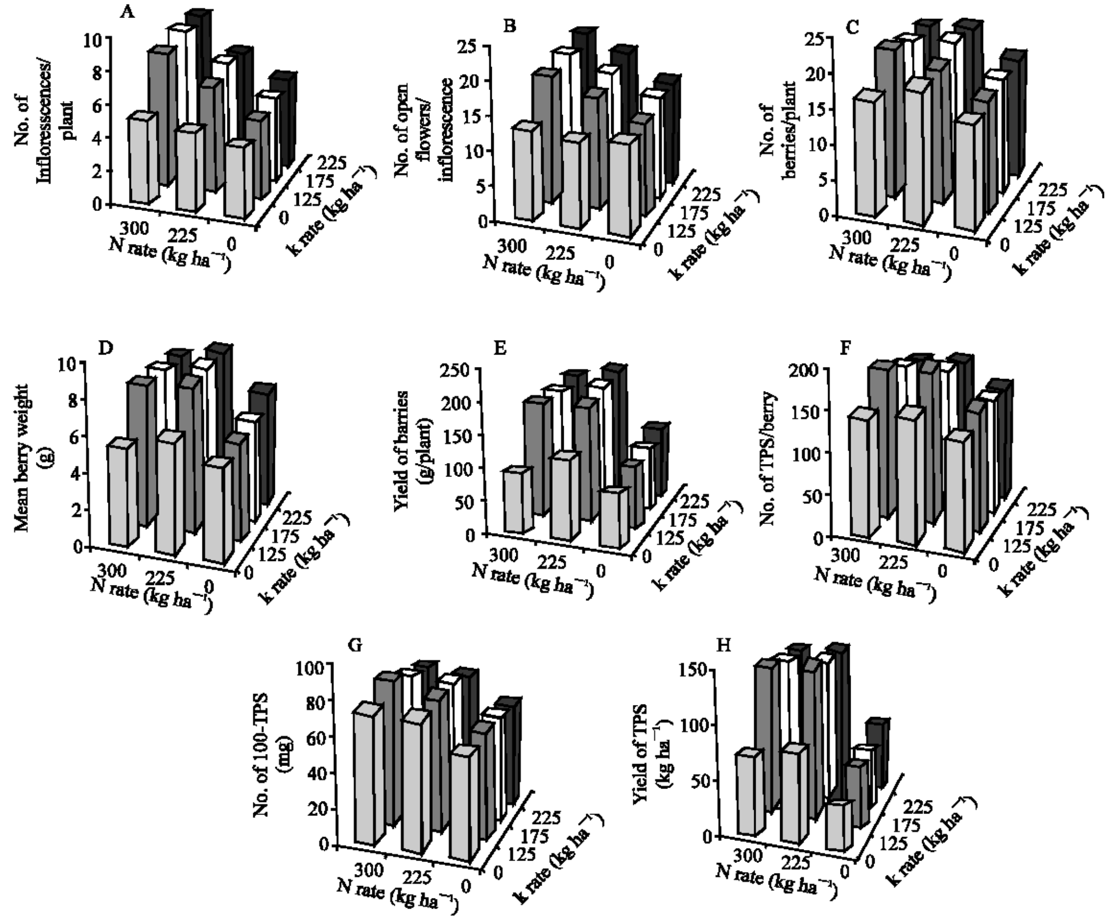

Fig. 1: Combined effects of different rates of N and K fertilizers on NIPP (A), NFPI (B), number of berries plant^{-1} (C), mean berry weight (D) yield of berries plant^{-1} (E), number of TPS berry^{-1} (F), weight of 100-TPS (G) and yield of TPS (H)

N or K significantly ($p \leq 0.01$) affected the number of berries plant^{-1}, but the effect of their combination was not significant, except at very high levels (Table 1 and 2). Mother plants supplied with $N_{225}K_{225}$ (22.7) produced 52% more berries plant^{-1} than those supplied with N_0K_0(14.9) (Fig. 1C). The number of medium-size berries was always higher than that of large and small ones, irrespective of the treatment combination (Table 2).

Different levels of N, K or their combination significantly ($p \leq 0.01$) affected the mean berry weight (Table 1). The highest mean berry weight (9.1 g) was obtained with the combination of $N_{225}K_{225}$, whereas the lowest (5.1 g) was obtained with N_0K_0 (Fig. 1D).

Different levels of N, K or their combination significantly ($p \leq 0.01$) affected the yield of berries plant^{-1} (Table 1). The yield of berries plant^{-1} decreased with increasing N rates, but increased with increasing K rates. The combination of $N_{225}K_{225}$ resulted in the highest yield, followed by $N_{225}K_{175}$ and $N_{300}K_{225}$ (207.2, 193.7 and 189.1 g plant^{-1}, respectively) (Fig. 1E).

Effect of N and/or K application on the number of TPS berry^{-1}: Different levels of N or K significantly ($p \leq 0.01$) affected the number of TPS berry^{-1} and their combination also had a significant effect ($p \leq 0.05$) but not on small-and medium-size berries (Table 1 and 2). There was a wide variation in the number of TPS berry^{-1} among small, medium and large-size berries (60, 184 and 252 TPS berry^{-1}, respectively) (Table 2). The combination of $N_{225}K_{125}$ resulted in the maximum number of TPS berry^{-1} which was similar to that obtained with $N_{300}K_{125}$ and $N_{225}K_{175}$ (196, 189 and 184, respectively) (Fig. 1F).

Effect of N and/or K application on 100-TPS weight: Different levels of N or K significantly ($p \leq 0.01$) affected 100-TPS weight (Table 1). The weight of TPS increased

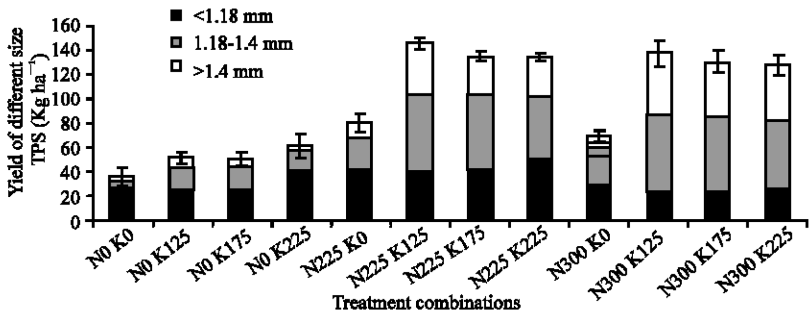

Fig. 2: Combined effects of different levels of N and K on size distribution of TPS yield. Vertical bars indicate SE (n = 3)

Table 2: Combined effects of different rates of N and K fertilizers on berry and TPS characteristics in MF-II x TPS-67

Treatment combination	No. of berries plant^{-1}			No. of TPS berry^{-1}			Wt. of 100-TPS (mg)		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
N_0K_0	6.6	7.3	1.0	46	140	207	56.6	57.9	59.3
N_0K_{125}	6.4	8.6	1.4	57	157	249	60.4	61.6	62.5
N_0K_{175}	6.2	9.3	1.3	54	152	242	59.3	60.8	64.5
N_0K_{225}	6.4	11.0	2.2	55	149	243	59.2	60.7	61.8
$N_{225}K_0$	6.2	11.2	1.6	59	185	214	70.2	72.5	73.5
$N_{225}K_{125}$	5.3	13.6	3.6	69	223	296	78.8	82.1	83.7
$N_{225}K_{175}$	4.0	14.4	3.7	66	209	277	76.7	79.5	80.2
$N_{225}K_{225}$	3.9	15.0	3.9	64	205	266	74.9	76.6	78.1
$N_{300}K_0$	4.2	9.9	1.8	54	177	205	72.4	74.3	75.8
$N_{300}K_{125}$	4.0	12.0	3.0	67	212	288	81.3	84.3	85.8
$N_{300}K_{175}$	4.0	14.1	3.2	64	205	271	78.2	81.6	82.3
$N_{300}K_{225}$	4.5	14.4	3.5	59	198	267	76.5	79.3	81.4
Mean	5.2	11.8	2.5	60	184	252	70.4	72.6	74.1
LSD (0.05)[x]	ns[y]	ns	0.55	ns	ns	16.16	1.64	1.71	2.02

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

with increasing N rates, but decreased with increasing K rates (Table 1). The N and K rates had opposite relationships with this parameter. Their interaction was also significant ($p \leq 0.05$) (Table 1 and 2). The weight of 100-TPS in small-, medium- and large-size berries ranged from 56.6 to 81.3 mg, 57.9 to 84.3 mg and 59.3 to 85.8 mg, respectively, among the treatment combinations (Table 2). The highest 100-TPS weight was produced by the combination of $N_{300}K_{125}$, closely followed by $N_{225}K_{125}$ and $N_{300}K_{175}$ (83.8, 81.5 and 80.7 mg, respectively) (Fig. 1G).

Effect of N and/or K application on yield of TPS: Different levels of N or K significantly affected ($p \leq 0.01$) the yield of TPS (Table 1). The value increased up to 225 kg N ha^{-1}, while $K_{125\text{-}225}$ produced similar yields (Table 1). The combination effect on total TPS yield was also significant ($p \leq 0.01$) (Table 1). The highest value was obtained with the combination of $N_{225}K_{125}$, followed by $N_{300}K_{125}$ (145.3 and 137.2 kg, respectively) (Fig. 1H).

Combined effects of different levels of N and K on TPS size distribution: Out of 12 treatment combinations, the highest yield of large-, medium- and small-sized TPS was obtained from $N_{300}K_{125}$ (59.3 kg ha^{-1}), $N_{225}K_{125}$ (55.6 kg ha^{-1}) and $N_{225}K_{225}$ (44.6 kg ha^{-1}), respectively (Fig. 2). Although total TPS yield was the highest with $N_{225}K_{125}$, followed by $N_{300}K_{125}$ (145.3 and 137.4 kg ha^{-1}, respectively), the distribution of large- and medium-sized berries with the latter was higher than that with the former (35 and 38% vs. 43 and 39%, respectively) (data not shown).

DISCUSSION

In the present study, all characters showed a significant single effect of N rate (Table 1). The highest values of number of berries plant^{-1}, mean berry weight, yield of berries plant^{-1}, number of TPS berry^{-1} and yield of TPS were found at 225 kg N ha^{-1}, which is similar to the findings of Upadhya *et al*. (1984), who made similar findings at 240 kg N ha^{-1}. All other reproductive characters, however, showed the highest values at 300 kg N ha^{-1}. The development of potato tubers strongly affects the reproductive growth because of competition between shoots and tubers (Veerman, 1998; Dwelle, 1985). Rapid tuberization, however, is prevented when N is applied interspatially because of successive growth of both shoots and roots (Krauss, 1978). In the present experiments, N was applied in 4 installments (at 10 day intervals starting 30 days after sowing) suggesting that tuberization should have been well prevented. Therefore, the effects of different N levels on the reproductive characters would not have been due to differences of tuber developments. In our experiment, 100-TPS weight increased with increasing N rate (Table 1). This was probably due to the fact that delayed senescence caused by N application allowed berries enough time to receive assimilates until a late stage of development. Some other researchers observed a similar relationship between N rate and 100-TPS weight (Marschner, 1995; Pallais *et al.*, 1987; Delouche, 1980).

Although K also affected reproductive characters of the potato mother plant, the effects were different from those of N (Table 1) and P (Roy *et al.*, 2006); i.e., flowering, berry setting and berry yield showed a positive response to K, while there was either a negative or poor response of the number of TPS berry^{-1}, 100-TPS weight and yield of TPS (Table 1). Moreover, the number of TPS berry^{-1} and 100-TPS weight decreased with increasing K rate (> 125 kg ha^{-1}), while $K_{125\text{-}225}$ produced similar TPS yields (Table 1). This was probably due to competition between tubers and aerial plant parts because K which is absorbed from the soil is predominantly incorporated into tubers rather than shoots (Kanzikwera *et al.*, 2001; Dubetz and Bole, 1975). In our experiments, tubers were not pruned in order to avoid mechanical damage of the roots and this might have contributed to the poor response of mother plants to K application. Kanzikwera *et al.* (2000) also found a similar relationship between K rate and TPS weight in Kisoro x Rutuku crosses.

Seed weight has been proposed as a character for selecting high-yielding TPS progenies (Dayal *et al.*, 1984). In our experiments, however, N and K applications showed an opposite relationship with 100-TPS weight (Table 1), as reported by Kanzikwera *et al.* (2000) and Karien *et al.* (1987) found for potato and maize, respectively.

The highest 100-TPS weight and yield were found with the combination of $N_{300}K_{125}$ and $N_{225}K_{125}$, respectively (Fig. 1G and H). Moreover, these combinations produced the highest yield of large-size TPS (Fig. 2). Seed size and 100-TPS weight larger than 1.18 mm and 75 mg, respectively, are regarded as indicating high quality seed (Upadhya *et al.*, 2003; Singh *et al.*, 1990; Dayal *et al.*, 1984; CIP, 1983). Application of N at 215 kg ha^{-1} increases seed size and larger seeds show faster germination and better seedling growth (Almekinders and Wiersema, 1991). Although $N_{225}K_{125}$ produced the highest TPS yield in our experiments, $N_{300}K_{125}$ would be better because the distribution of the seeds larger than 1.18 mm was the highest with this combination (Fig. 2).

Considering the present results together with those of our previous study (Roy *et al.*, 2006), we conclude that the combination of 300 kg N, 120 kg P and 125 kg K ha^{-1} was the most suitable for the commercial production of hybrid TPS from ♀MF-II x ♂TPS-67.

ACKNOWLEDGMENT

This study was supported by Ronpaku program of JSPS (Japan Society for the Promotion of Science).

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