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Optimum Level of Organic and Inorganic Fertilizers Requirement for the Sustainable Productivity of Two Pipeline Clones of Potato

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Abstract

The response of two pipeline potato clones to various levels of major nutrients (N: P_2O_5 and K_2O) was studied during 2010/11 to 2011/12 at Hattiban Potato Research Farm, Khumaltar, Lalitpur. An experiment was laid out in a split plot design with three replications considering combinations of six different fertilizer levels as the main plot and three potato clones as sub-plot. The use of different doses of chemical fertilizers and 20 mt/ha farm yard manure (FYM) did not bring any improvements on soil properties. However, soil pH was slightly improved. The effect of different doses of chemical fertilizers was non-significant on plant emergence (at 30 DAP), ground cover and plant uniformity at 55 DAP. However, increased dose of N and K fertilizer gave taller plants and increased number of main stems per plant. Variety Kufri Jyoti performed better than both of the tested clones in the parameters such as plant emergence, ground cover and number of main stems per plant. Interaction effect was highly significant on number of stems per plant. Highest number of under and seed sized tubers were produced in the treatment with 100:100:60 N: P_2O_5: K_2O kg/ha with 20 mt/ha, whereas highest number of over sized potato tubers were produced in the treatment 150:100:60 N: P_2O_5: K_2O kg/ha and 20 mt/ha FYM. Total number of tubers and total weight (kg) was obtained highest in the treatment of 100:100:60 N: P_2O_5: K_2O kg /ha with 20 mt/ha FYM. Variety Kufri Jyoti is still better yielding if there is no late blight disease in growing season. Though numbers of undersize and seed size tubers were produced highest from clone L 235-4, variety. Kufri Jyoti potato variety still is doing better in hill conditions of Nepal if the environment is not conducive to *Phytophthora* pathogens. Variety Kufri Jyoti has been able to produce highest yielded (30.9 t ha^{-1}) in the application of 150:100:60 N: P_2O_5: K_2O kg/ha and 200:100:60 N: P_2O_5: K_2O kg/ha with 20 mt/ha FYM, whereas clone L 235-4 gave the highest yield (29.4 t ha^{-1}) and clone CIP 389746.2 yielded highest (25.5 t ha^{-1}).

Key words: L 235-4 and CIP 389746.2, N, P_2O_5, K_2O, FYM, Potato

Introduction

Potato (*Solanum tuberosum*, L.) is one of the important cash crops in Nepal with 182,600 ha being grown in 2010/11 as compared to only 84,280 ha in 1990 and 129,029 in 2000/01 (ABPSD 2011). It is grown in almost all types of agro-climatic zones and soil types of Nepal. Majority population of Nepal consumes more potatoes than any other cereals and vegetables except rice (Niraula *2008*). Due to this fact, per capita consumption has also been estimated at one of the very high level in the world (61 kg/year). But the average yield level is still low at 13.7 mt/ha if compared to both of the neighboring countries (FAOSTAT, 2011), which could be due to unbalanced and inadequate use of fertilizers, varietal impurity, non-availability of quality seed and other factors (Luitel *et al*. 2008, Bhattarai and Pandey 2010).

Breeders often put emphasis on identification of varieties that are high yielding and disease resistant. But newly developed varieties sometimes may not give expected results in farmers' fields. It is therefore necessary to obtain new varieties to be more appealing to the farmers requiring less change in farming practice and input demand (Kakuhen *et al.* 2005).

Potato is a heavy nutrient feeder crop and its shallow root system and rapid growth rate necessitates a good supply of plant nutrients for obtaining higher yield (Pandey 1991). There are 13 essential mineral elements, which are taken up in various quantities by the crop. Among them nitrogen is an essential constituent of protein and chlorophyll where as potassium helps in translocation of carbohydrate and enhances plant resistance to withstand major abiotic stresses such as drought and frost (Singh & Raghav 2000). Nitrogen increases the vegetative growth, crop duration and quality of tubers and decides the yield level too (Perrenoud 1993). A crop yielding 30 mt/ha of tubers has been estimated to take 150 kg N, 60 kg P_2O_5, 350 kg K_2O, 90 kg CaO and 30 kg MgO from the soil during its growth and development (Beukema & Vander Zaag 1979).

Fertilizer needs of the crop not only do vary with growing conditions, but also do with varieties and nutrient interaction (Trehan & Grewal 1997). But despite of differences in varietal response to fertilizer doses, potato growers in the country have yet to rely on flat recommendations available in all the varieties which is 100:100:60 N: P_2O_5: K_2O kg/ha + 20 mt/ha FYM or compost (Khatri & Shrestha 1998). Current fertilizer recommendations based on old potato varieties and crop practices cannot be valid for newer varieties as nutrient requirement may differ with them considerably. So, prior to release or recommend any potato clones as varieties for commercial production, information on the requirement of major nutrients needs to be verified and the optimum dose of major nutrients has to be standardized, as well. Therefore, this investigation was undertaken to find out the optimum level of both the doses of N: P_2O_5: K_2O kg/ha for two pipeline clones of potato and make recommendations to the potato grower farmers of Nepal.

Methodology

An experiment was conducted at Hattiban Potato Research Farm, Khumaltar, Lalitpur (1340 masl) during the years 2010/011 and 2011/012. Two pipeline clones used in the field experiment were L 235-4 and CIP 389746.2 and variety Kufri Jyoti was used as a check variety. Fertilizer level combinations were control (no application of fertilizers and manures), 0:100:60, 100:100:60, 150:100:60, 200:100:60 and 150:100:90 N: P_2O_5: K_2O kg/ha respectively. Farm yard manure (FYM) was applied @ 20 mt/ha in all the treatments except in control. The sources of chemical fertilizers were di-ammonium phosphate (18:46:0), urea (46:0:0) and muriate of potash (0:0:60 kg/ha^{1}). The experiment was laid out in split a plot design considering potato clones as the main plot and six fertilizer levels as sub-plots.

A single plot size was maintained at 5.4 m^2 and bonds of 60 cm were placed between two plots. Excluding the control plots the FYM was applied at the rate of 20 mt/ha in each treatment plots. The row to row spacing in each plot was maintained at 60 cm and plant to plant 25 cm. Full dose of both organic manures (FYM) and chemical fertilizers as per the requirement of the treatments were applied in furrows and mixed thoroughly before planting the crop. All other cultural practices were followed as per the recommendations of Potato Research Programme. Observations were taken for plant emergence at 30 and 45 days after planting (DAP), ground cover, average number of main stems per plant and plant height at crop standing stage and tuber size distribution based on number and weight categories, total number and weight per plot and total tuber yield etc at the harvesting time.

The seed tubers of all the clones including check variety were of approximately 30 to 50 g in size. The crop was irrigated immediately after planting to support the emergence. Other irrigations were provided when necessary. For controlling late blight disease, the plants were treated twice with mancozeb and only once with metalaxil. Composite soil samples were taken from each treatment fields before planting and immediately after harvesting of the potato tubers.

Soil samples were analyzed to determine the soil reaction (pH), organic matter (OM %), total nitrogen (N %), available phosphorous (P_2O_5 kg /ha) and available potassium (K_2O kg/ha) content. The soil of the experimental site was observed to be alluvial (Inceptisol) with silty-loam texture. The chemical properties of the soils were analyzed in every year after potato crop harvest following modified Kjedahl distillation for nitrogen, modified Olsen's method for phosphorus and Flame photometer for potash respectively. Yield and yield parameters of two years (2010/11 and 2011/12) were combined for statistically analysis and using the Gen-stat 532-2 programme.

Results and Discussion

Effect on soil physicochemical properties

In the bench mark soil analysis, the soil reaction was found strongly acidic (4.5 pH), soil organic matter and nitrogen content were at medium level. The available potassium (161 kg/ha) and phosphorus (307 kg/ ha) were at medium and very high level respectively (Table 1). Average of two years' soil testing results revealed that the soil pH was slightly improved by the application of organic manure and balance dose of mineral fertilizers. Continuous application of different combinations of organic, inorganic and control treatments for two years did not affect the total nitrogen but the level of organic matter; available phosphorus and available potash in the soil were depleted in different levels which further indicated that potato was a heavy feeder crop.

Table 1. Soil properties in the experimental plots as affected by organic and inorganic fertilizers; average of two years (2010/11 and 2011/12)

	Physicochemical properties of soil							
						Soil Texture		
						Sand	Clay	Silt
Treatments	Soil pH	OM (%)	N (%)	P_2O_5 (kg/ha)	K_2O (kg/ ha)	(%)	(%)	(%)
Benchmark	**4.5**	**4.525**	**0.17**	**307.7**	**161**	-	-	-
T_1.Control	5.05	3.78	0.162	231.65	97.45	16.1	14.6	67.2
T_2. 0:100:60 N:P_2O_5 K_2O kg + FYM 20 t ha^{-1}	5.15	4.11	0.169	296.95	166.35	16.2	15.0	68.8
T_3. 100:100:60 kg N:P_2O_5 K_2O + FYM 20 t ha^{-1}	5.05	4.36	0.178	275.7	143.15	16.3	15.6	68.3
T_4.150:100:60 kg N:P_2O_5 K_2O +FYM 20 t ha^{-1}	4.85	4.00	0.1635	319.8	156.85	16.4	17.3	68.1
T_5.200:100:60 kg N:P_2O_5 K_2O +FYM 20 t ha^{-1}	4.85	4.36	0.168	317.85	141.25	16.2	16.3	68.6
T_6.150:100:90 kg N:P_2O_5 K_2O +20 FYM t ha^{-1}	4.9	4.30	0.1665	303.1	182.8	16.6	15.6	68.1
Mean	**4.97**	**4.155**	**0.168**	**290.8**	**147.98**	**16.3**	**15.7**	**68.2**

Effect of different fertilizer levels on morphological traits of potato clones

At thirty days after planting (DAP), highest emergence percentage (61%) was counted in the control plots (no fertilizer), whereas in other plots, it remained below fifty percent (Table 2). In second observation of 45 DAP; significant results observed between the treatments. There was no significant difference observed on ground cover (%). There were not much numerical differences observed on ground cover between control and zero nitrogen treatments, and levels of nitrogen at 100, 150 and 200 kg N/ha. Plant height (cm) was highly affected by nitrogen fertilizer.

With the increment of N fertilizer, the plant height also increased to highly significant level. Plants from control plots were slightly more uniform than in other treatments. The differences between control and zero nitrogen treatment with treatment number 2, 3, 4 and 5 were highly significant. A highly significant difference between the treatments on average number of main stems per plant was also highly significant. Highest number of stems were counted on the treatment 150:100:90 N: P_2O_5: K_2O kg/ha and 20 mt/ha FYM. Plant uniformity was not affected by the fertilizer level. however, highest uniformity (3.2 in 1 to 5 scales) observed in control treatment.

The interaction effect between the treatments and potato clones (varieties) was not-significant in plant emergence at both of the observations, however, at 30 DAP plant emergence was counted highest in T_1 x V_1 (79), but it reached almost equal number in second observation (45 DAP).

Ground cover among the tested clones was highly significant, probably influenced by the emergence rate. Plants of the clone CIP 389746.2 were measured tallest (53.8 cm) in height followed by another clone L 235-4 (47.5 cm) and variety Kufri Jyoti (46.5 cm). Average number of main stems was counted highest in Kufri Jyoti (4.6) and lowest in CIP 389746.2 (3.9). The treatments alone or in combination with potato clones (varieties) did not have any effect on plant emergence, but ground cover, plant height and main stems per plant were highly influenced by fertilizer levels, since all the four treatments were superior to the control. Plant uniformity was not affected by the treatments in

the field experiment. Highest number and weight of undersize tubers were produced by the control treatment Recommendations of major nutrients (100:100:60 N: P_2O_5: K_2O kg/ha + 20 mt/ha FYM) by the Potato Research Program (PRP)/Nepal agricultural Research Council (NARC) seem still justifiable in both vegetative and yield performance.

The interaction effect between the treatments and varieties was not found significant in plant emergence at both of the observations dates. Ground cover, plant height and uniformity were also unaffected. Highly significant difference was found in number of main stems per plants (Table 2). There were numerical differences between the treatments combinations with varieties in all the parameters recorded in the trial. Similarly, ground cover was observed highest (47) in T3 x V1 and lowest in T2 x V2 (29). Tallest plants were found in the treatment 6 xV3 (63.7 cm) whereas shortest in T1 x V1 (30.5 cm). Average number of main stems per plant was found almost the same in the combinations of T3 x V2 (4.9), T6 x V1 (4.8), T6 x V2 (4.7) and T3 x V1 (4.6) respectively. Plants were more uniform in combinations of T1 x V2 and T1 x V2.

Table 2. Effect of different level of fertilizers and clones on vegetative characteristics of potato at Khumaltar, Lalitpur, average of two years (2010/11 and 2011/12).

Treatments	Plant emergence (%)		Ground Cover (%)	Plant Height (cm)	Stem /plant (#)	Plant uniformity (1-5 scale)
	30 DAP	45 DAP				
Factor A (Treatments)						
1. Control (0:0:0 N: P_2O_5: K_2O + 0 FYM)	61	99	37	34.9	3.6	3.2
2. 0:100:60 N: P_2O_5: K_2O kg +FYM 20 t ha^{-1}	50	98	38	38.7	3.9	3.0
3. 100:100:60 N: P_2O_5: K_2O kg +FYM 20 t ha^{-1}	49	97	42	52.5	4.5	3.0
4. 150:100:60 N: P_2O_5: K_2O kg +20 t FYM t. ha^{-1}	43	98	38	56.4	4.6	2.9
5. 200:100:60 N: P_2O_5: K_2O kg +FYM 20 t ha^{-1}	44	92	37	56.7	4.3	2.8
6. 150:100:90 N: P_2O_5: K_2O kg +20 FYM t ha^{-1}	47	97	39	56.3	4.7	2.9
F-test	NS	*	NS	**	**	NS
LSD (0.05)	-	3.265	-	4.964	0.566	-
Factor B (Varieties)						
1. Kufri Jyoti	63	98	42	46.5	4.5	3.0
2. L 235.4	37	96	33	47.5	4.4	3.0
3. CIP 389746.2	47	96	40	53.8	3.9	3.0
F-test	**	NS	**	**	**	NS
LSD (0.05)	15.91	-	4.97	3.51	0.40	-
Interaction (TxV)						
T1XV1	79	99	38	30.5	3.7	3.2
T1XV2	44	98	31	35.2	3.6	3.5
T1XV3	61	99	42	39.3	3.5	2.8
T2XV1	73	99	43	35.8	**4.4**	3.0
T2XV2	34	97	29	36.4	3.8	3.0
T2XV3	43	99	42	43.8	3.7	3.0
T3XV1	61	99	47	50.9	**4.6**	3.0
T3XV2	42	95	34	51.6	**4.9**	3.0
T3XV3	46	99	46	54.9	4.0	3.0
T4XV1	45	98	39	54.9	4.9	3.0
T4XV2	38	97	34	53	4.6	2.8
T4XV3	46	98	41	61.3	4.3	2.8
T5XV1	61	99	43	54.8	4.6	3.0
T5XV2	31	94	33	55.3	4.9	2.7
T5XV3	40	87	35	59.9	3.5	2.7
T6XV1	58	96	44	51.8	**4.8**	3.0
T6XV2	36	95	35	53.5	4.7	2.8
T6XV3	49	99	38	63.7	4.4	3.0
F-Test	NS	NS	NS	NS	**	NS
LSD (0.05)	-	-	-	-	0.979	-
CV (%)	38.98	5.1	12.1	8.599	19.9	30.0

The interaction effect between the treatments and potato clones (varieties) was not-significant in plant emergence at both of the observations, however, at 30 DAP plant emergence was counted highest in T_1 x V_1 (79), but it reached almost equal number in second observation (45 DAP).

Ground cover among the tested clones was highly significant, probably influenced by the emergence rate. Plants of the clone CIP 389746.2 were measured tallest (53.8 cm) in height followed by another clone L 235-4 (47.5 cm) and variety Kufri Jyoti (46.5 cm). Average number of main stems was counted highest in Kufri Jyoti (4.6) and lowest in CIP 389746.2 (3.9). The treatments alone or in combination with potato clones (varieties) did not have any effect on plant emergence, but ground cover, plant height and main stems per plant were highly influenced by fertilizer levels, since all the four treatments were superior to the control. Plant uniformity was not affected by the treatments in the field experiment. Highest number and weight of undersize tubers were produced by the control treatment Recommendations of major nutrients (100:100:60 N: P_2O_5: K_2O kg/ha + 20 mt/ha FYM) by the Potato Research Program (PRP)/Nepal agricultural Research Council (NARC) seem still justifiable in both vegetative and yield performance.

The interaction effect between the treatments and varieties was not found significant in plant emergence at both of the observations dates. Ground cover, plant height and uniformity were also unaffected. Highly significant difference was found in number of main stems per plants (Table 2). There were numerical differences between the treatments combinations with varieties in all the parameters recorded in the trial. Similarly, ground cover was observed highest (47) in T3 x V1 and lowest in T2 x V2 (29). Tallest plants were found in the treatment 6 xV3 (63.7 cm) whereas shortest in T1 x V1 (30.5 cm). Average number of main stems per plant was found almost the same in the combinations of T3 x V2 (4.9), T6 x V1 (4.8), T6 x V2 (4.7) and T3 x V1 (4.6) respectively. Plants were more uniform in combinations of T1 x V2 and T1 x V2.

Effect of different fertilizer levels on potato clones yield parameters

The highest number of under size tubers (<25 g) were harvested from the treatment no. 3 (100:100:60 N: P_2O_5: K_2O kg/ha +20 mt/ha FYM) followed by treatment no. 6 (150:100:90 kg N: P_2O_5: K_2O kg/ha +20 FYM) and treatment no.4 (150:100:60 N: P_2O_5: K_2O kg/ha +20 mt/ha FYM) respectively (Table 3). But highest weight of under size tubers was obtained from the treatment no.1 followed by treatment no. 2 (%). The differences between treatments on undersize tuber production was found highly significant but non-significant on weight in this size category. Treatment no. 3 with 100:100: 60 N: P_2O_5: K_2O kg/ha and 20 mt/ha FYM gave highest number of seed size tubers (172) whereas control (treatment no. 1) produced highest seed size tuber (61). Highest number and average weight (46) of oversize tubers were harvested from treatment no. 4 (66) and lowest in treatment no. 1. Lowest number and weight of oversize tubers were obtained from treatment no. 1 followed by treatment no. 2. Total number of tubers were obtained highest from the treatment no. 3 (331) followed by treatment no. 6 (327), treatment no. 4 and no. 5, respectively. Almost double numbers of tubers were harvested from all the treatments than the control treatment (196). Treatment no. 4 produced highest total weight per plot yield (23.6 kg) and treatment no. 1 produced the lowest (9.8 kg). Highest yield mt/ha was obtained from treatment no. 6 (28.4 mt/ha) followed by treatment no. 4 (27.9 mt/ha) and 26.2 mt/ha from treatment no. 5 (26.2 mt/ha). The control treatment had almost half tuber yield compared to other treatments except treatment no. 2 (18.5 mt/ha). Except on the undersize weight category of tuber yield, a highly significant difference was observed in all other parameters observed.

Varietal differences were highly significant at all of the parameters assessed in yield factors except in number of oversize tuber distributions and total weight per plot. The clone L 235-4 produced highest number of undersize and seed size tubers compared to other tested clone and check variety Kufri Jyoti whereas the highest number and weight of oversize tubers were obtained from clone 389746.2. Total number (401) and weight (20.4 kg) of the tubers per plot were obtained highest from the clone L 235-4 followed by Kufri Jyoti. Among the clones tested Kufri Jyoti was found highest yielder (25.4 mt/ha) followed by L 235-4 (24.1 mt/ha).

The interaction effect between two factors (fertilizer level and potato clones) was found non-significant on all three tuber size categories in each treatment results except in seed size numbers and total tuber number per plot. The treatment effect on undersize tuber weight showed no significant differences.

Table 3. Effect of different level of fertilizers and potato clones on tuber yield, average of two years (2010/11 and 2011/12)

Treatments	Tuber size distributions No. & wt %)						Total/plot (5.4 m^2)		Yield (t/ha^{-1})
	< 25g		25-50g		>50g				
	No.	%	No.	%	No.	%	No.	Wt kg	
Factor A (Treatments)									
1. Control (0:0:0 N: P_2O_5: K_2O + 0 FYM)	62	10	110	61	24	29	196	9.8	14.0
2. 0:100:60 N: P_2O_5: K_2O kg ha^{-1} + FYM 20t ha^{-1}	84	9	130	55	38	36	253	14.5	18.5
3. 100:100:60 N: P_2O_5: K_2O kg ha^{-1}+FYM 20 t ha^{-1}	109	8	172	50	50	42	331	21.4	26.1
4. 150:100:60 N: P_2O_5: K_2O kg ha^{-1} +FYM20t ha^{-1}	100	8	156	46	66	46	322	23.6	27.9
5. 200:100:60 N: P_2O_5: K_2O kg ha^{-1} +FYM 20 t ha^{-1}	98	8	161	49	57	43	317	21.9	26.2
6. 150:100:90 N: P_2O_5: K_2O kg ha^{-1} +20 FYM t ha^{-1}	106	7	164	49	57	44	327	23.4	28.4
F-test	**	ns	**	**	**	**	**	**	**
LSD (0.05)	27.31	-	23.0	7.54	20.59	9.12	32.46	7.56	3.252
Factor B (Varieties)									
1. Kufri Jyoti	91	8	147	52	55	40	293	19.6	25.4
2. L 235.4	146	12	213	65	42	24	401	20.4	24.1
3. CIP 389746.2	42	5	86	38	50	57	178	17.3	21.1
F-test	**	**	**	**	ns	**	**	ns	**
LSD (0.05)	15.78	1.71	16.27	5.33	-	6.45	22.95	-	2.299
Interaction (T x V)									
T1XV1	63	10	116	67	30	24	208	9.3	14.0
T1XV2	94	14	147	73	13	13	254	10.1	14.4
T1XV3	28	6	68	44	30	50	126	10.2	13.6
T2XV1	89	9	147	58	52	34	288	14.8	20.5
T2XV2	121	13	162	65	24	23	308	14.9	17.9
T2XV3	43	5	82	44	38	51	163	13.7	17.2
T3XV1	106	7	167	52	53	41	326	20.7	25.8
T3XV2	173	12	254	65	40	24	468	22.6	27.6
T3XV3	48	5	94	35	56	61	199	20.8	24.9
T4XV1	90	9	142	42	70	50	302	24.7	30.9
T4XV2	168	11	240	61	65	28	473	25.4	28.7
T4XV3	43	5	85	34	64	61	193	20.8	24.0
T5XV1	92	7	160	49	62	45	314	24.8	30.9
T5XV2	164	12	236	63	58	25	458	23.3	26.5
T5XV3	39	5	87	36	52	59	178	17.5	21.1
T6XV1	107	8	153	47	61	45	321	23.2	30.2
T6XV2	158	9	239	62	51	30	448	25.9	29.4
T6XV3	52	5	101	37	58	58	210	21.0	25.5
F-Test	NS	NS	*	NS	NS	NS	**	NS	NS
LSD (0.05)	-	-	39.8	-	-	-	56.2	-	-
CV (%)	36.1	43.7	23.3	22.0	63.8	34.5	16.9	59.8	20.9

The verification of field experiment on optimum level of nutrients requirement conducted on two pipeline clones of potato at Khumaltar, Lalitpur conditions showed that there was no varietal effect in the parameters assessed. Plant height and tuber yields were highly dependent on the amount of N applied, whereas the recommendations of 100:100:60 N: P_2O_5: K_2O kg/ha along with 20 mt/ha FYM is still valid in Khumaltar conditions, however, the highest tuber yield was obtained in the treatment level with 150:100:90 N: P_2O_5: K_2O kg/ha plus 20 mt/ha FYM compared to other treatments in the trial.

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