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EFFECT OF ORGANIC AND CHEMICAL FERTILIZER ON GROWTH AND YIELD OF POTATO (*Solanum tuberosum*) VARIETIES IN NEPAL

S. Bhujel[1], C. Pant[1*] and S. Sapkota[2]

[1]Department of Agronomy, [2]Department of Agri-botany and Ecology

Agriculture and Forestry University, Rampur, Chitwan

ABSTRACT

An experiment was conducted to evaluate the yield performance of potato varieties with chemical and organic fertilizer at Chilime, Rasuwa. The experiment consisted of eight treatment combinations laid out in two factors Randomized Complete Block Design (RCBD) with three replications. Four potato varieties (Khumal-Seto-1, Khumal-Ujjwal, Janak-Dev and Kufri-Jyoti) with fertilizer (Recommended dose of chemical fertilizer (100:100:60 NPK kg ha^{-1}) and organic farmyard manure (15 mt ha^{-1}) were used to make eight treatment combinations. The results showed that Janak-Dev had the highest plant height (69.3 cm) and canopy diameter (60.92 cm). Khumal-Seto-1 had highest number of main stems per hill (3.75) which were statistically similar to Kufri-Jyoti (3.42) and Khumal-Ujjwal (3.25). Janak-Dev had the lowest number of main stems per hill (1.87). The effect of fertilizer was non-significant. Flowering occurred earlier in Janak-Dev at 61.17 days after sowing while Kufri-Jyoti flowered after 73.17 days after sowing. The highest number of tubers were found in Khumal-Seto-1 (9.167) and lowest in Janak-Dev (5.750). Number of tubers per plant was not affected by types of fertilizers used. Maximum weight of each tuber (107.7 grams), yield per plant (780 grams) and yield per hectare (37.1 mt ha^{-1}) were obtained from Kufri-Jyoti. These parameters were the highest from chemical fertilizer application. This field experiment showed that Kufri-Jyoti with recommended dose of chemical fertilizer was appropriate to get optimum yield under Chilime condition.

Keywords: Fertilizers, Potato, Tuber, Varieties, Yield

Potato (*Solanum tuberosum*) belongs to order Solanales in Solanaceae family of flowering plants (Grun, 1990). It is the third most important crop in terms of human consumption after rice and wheat; in 2016, 376.83 million metric tons of potato was produced from 19.25 million hectares land (CIP, 2017).

*Corresponding author: pantchudamani@gmail.com

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According to MoAD (2019), potato is cultivated in 195,173 ha producing 2,881,829 metric tons. Potato ranks fifth on area coverage, second in production and consumption, and ranks first in productivity. Potato is cultivated at an altitude ranges between 100m to 4400m (Joshi, 1997). Gatlang-Local, Khumal-Ujjwal, Khumal-Seto-1, Janak-Dev, Kufri-Jyoti etc. are the major varieties of potato grown in Rasuwa district of Nepal. Fertilizer application has an important effect on yield (Wastermann, 2005). Varietal selection is another contributing factor for potato production. If the seed is healthy and of good quality, yield can increase up to 40% (Khairgoli, 1987). Potato demands high amount of nutrients as it has poorly developed shallow root system as compared to its yield. Potato produces large amount of dry matter as compared to cereals (Singh and Trehan, 1998). Large amounts of soil nutrients are depleted and the loss in nutrients are alarming. Hence inputs application like Nitrogen, Phosphorus and Potassium are essential and these major macronutrients have shown improvements in yield and quality (Wastermann, 2005). Daily requirement for growth of potato tubers during bulking stage are 4.5 kg ha^{-1} N, 0.3 kg ha^{-1} P and 6.0 kg ha^{-1} K (Haifa, 2014). Nitrogen is essential for increasing plant height, leaf area index, shoot dry matter and tuber yield (Zelalem et al., 2009). Phosphorus is required for early growth and tuber maturity (UIES, 2010). Potassium is necessary for translocation of carbohydrates and enhances the plant resistance against diseases and abiotic stresses like drought and heat (Pandey, 2000).

The excessive use of chemical fertilizers is also harmful for soil health. The microbial activities are disturbed, infiltration and productivity are reduced. The use of chemical fertilizers can increase tubers but it has negative effects on tuber quality, environmental pollution, public health and economic losses; starch and sugar contents are reduced in tubers (Alva, 2004). During storage, if potatoes are not taken care, the loss of tuber quality could be more. Animal manure can improve chemical, physical and biological characteristics of the soil. Use of compost in agriculture fields is must for sustainable agriculture. Organic fertilizer has beneficial effects including hydraulic conductivity, improves water holding capacity, regulates soil pH, enhances soil aggregation and reduces incidence of diseases (Olson and Papworth, 2006). Combining inorganic fertilizer and organic manure showed significant effect particularly on yield parameters of potato (Suh et al., 2015). Integrated nutrient management is essential for sustainable potato production. Integrating organic fertilizer is very important for increasing potato yield and maintaining soil health. It also reduces the cost of production, as purchase of mineral fertilizers are reasonably expensive in markets for poor farmers.

MATERIALS AND METHODS

The experiment was conducted in farmer's field at Chilime, Rasuwa (28.182409^0 N, 85.302447^0 E), Province-3, Nepal at an altitude of 1738 meters above mean sea level. Chilime is located at 30 km north from Dhunche, headquarters of Rasuwa. The average maximum and minimum temperature of the district are 29.2°C and 8.10°C respectively (DADO, 2019). Chilime comes under subtropical climate.

Composite soil sample was randomly taken from different locations in field using screw auger to record the initial soil physical and chemical properties of the experimental site. Soil pH that affects the availability of mineral nutrients with value of 7.0 (Neutral). The total carbon and nitrogen content was 3.60% (Medium) and 0.18% (Medium). Similarly, available phosphorus and potassium content were high having values of 93.70 kg ha^{-1} and 360.20 kg ha^{-1} respectively. Soil texture was sandy loam.

The experiments were laid out in two factors Randomized Complete Block Design (RCBD) with 8 treatments having 3 replications and the treatments were randomly allocated using random number table. The total experimental area was 129.71 m^2 (10.9m X 11.9m) having space between replications and plots with 1.0m and 0.5m respectively. The individual plot size was 2.1m × 0.9m i.e., 1.89m^2. The row-to-row distance was 70 cm and plant to plant distance was 30 cm. There were three rows in each plot and three plants were planted in each row. Four sample plants were selected randomly for observation.

Factor 1: Varieties

1. Janak-Dev (V1)
2. Khumal-Ujjwal (V2)
3. Khumal-Seto-1 (V3)
4. Kufri-Jyoti (V4)

Factor 2: Fertilizer

1. Government Recommended dose of fertilizer (100:100:60 NPK kg ha^{-1} (RDF)
2. Farmyard manure (FYM) @15 t ha^{-1}

The recommended dose of nitrogen (100 kg ha^{-1}) was applied through Urea (46% N) and Di-ammonium phosphate (18% N, 46 % P_2O_5) in the treatment for chemical fertilizer: phosphorus (100 kg ha^{-1}) from Di-ammonium phosphate (46 % P_2O_5) and potassium (60 kg ha^{-1}) from Muriate of Potash (60% K_2O). Half dose of nitrogen and full dose of phosphorus and potassium were applied at the time of sowing. Remaining half dose was broadcasted at 50 and 75 days after sowing in equal amounts. Well sprouted potato seeds were sown on 29th January with a spacing of

70cm × 30cm. As the field was dry, light irrigation was provided a week before sowing. Irrigations were given at 25 DAS, 45 DAS, 65 DAS and 80 DAS. First manual earthing up and side dressing with urea were done at 50 DAS and second at 75 DAS. Haulm pulling was done at 117 DAS and potato was harvested at 128 DAS.

The first data collection was done at 45 DAS from sample plant and subsequent data were taken at 15-day interval. The data related to plant height, Days to 50% Flowering, Number of tubers per plant, weight of each tuber, Yield per plant and Yield per hectare.

Statistical Analysis

Microsoft Excel and GenStat fifteenth edition were used for analysis of different parameters. Data were subjected to analysis of variance (ANOVA) to find out the significance of treatment effect. Means of the treatment were compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance.

RESULTS AND DISCUSSION

Plant Height

Plant height of different varieties were significant after 75 DAS (Table 1). The highest plant height was found in Janak Dev at all stages of growth. At 105 DAS, Janak Dev was the tallest (69.3 cm) followed by Kufri Jyoti and Khumal Ujjwal (48.6 and 48.1 cm respectively). The variations in plant height among varieties were most probably due to plant genetics and quality of plant materials used (Eaton et al., 2017).

Statistical analysis showed that there was significant effect with the application of organic fertilizer with regard to plant height at 45 DAS, 60 DAS and at 75 DAS and effect of inorganic fertilizer was highly significant at 90 DAS and at 105 DAS. Mean height of plant treated with inorganic fertilizer at 105 DAS was 54.1 cm which was significantly higher than plant (46.5 cm) treated with organic fertilizer.

The lower height during early stage of growth in plants treated with inorganic fertilizer might be due to salt toxicity on developing sprouts (Rosen and Bierman, 2017). The non-significant difference in height at 75 DAS and this was largely due to utilization of reserved nutrient materials in the mother tuber (Love and Thompson-Johns, 1999) and (Kabir et al., 2004). At later stages of growth, the root assimilation of nutrients with inorganic fertilizers caused significant difference in plant height. The increased height of plants with inorganic fertilizer during late stages could be due to increased metabolic activities in crops with optimum fertility (Krishnappa, 1995).

Table 1. Effects of varieties and fertilizers on plant height at different growth stages of potato at Chilime, Rasuwa, 2019

Treatments	Height of plant(cm)				
	45DAS	60 DAS	75 DAS	90 DAS	105DAS
Varieties					
Janak Dev	10.04	19.71	45.58[a]	65.8[a]	69.3[a]
Khumal Ujjwal	7.83	15.25	35.58[b]	46.5[b]	48.1[b]
Khumal Seto-1	7.50	17.46	28.04[c]	33.8[c]	35.2[c]
Kufri Jyoti	9.00	17.12	29.75[c]	47.2[b]	48.6[b]
SEm (±)	0.72	1.14	1.570	2.04	2.23
LSD (=0.05)	Ns	Ns	4.76***	6.20***	6.77***
Fertilizer					
RDF	6.77	15.65	34.98	52.50	54.10
FYM	10.42	19.12	34.50	44.10	46.50
SEm (±)	0.51	0.80	1.11	1.45	1.58
LSD (=0.05)	1.55***	2.45**	NS	4.38***	4.78**
CV (%)	20.7o	16.10	11.10	10.40	10.90
Grand Mean	8.59	17.39	34.74	48.30	50.30

Note: The treatment mean followed by common letters in same column does not significantly differ from each other based on DMRT at 5 % level of significance.

Days for 50% flowering

Days for 50% flowering' was found highly significant among the varieties (Table 2). Flowering occurred earliest (61.17 days) in Janak Dev followed by Khumal Ujjwal and Khumal Seto-1 in which 50% flowering occurred after 71.83 days after sowing. 50% flowering was at last in Kufri Jyoti (73.17 DAS).

Days for 50% flowering might be influenced by varietal character. 'Days for flowering' is also influenced by temperature and other external environmental factors.

Effect of fertilizer on days for 50% flowering was non-significant. It took 69.75 and 69.25 days for flowering in plants treated with inorganic and organic fertilizers respectively. Non-significantly delay in flowering in plants treated with inorganic fertilizers might be due to prolongation of vegetative stage with the effect of nitrogen (Ojala et al., 1990).

Table 2. Effect of varieties and fertilizers on days for 50% flowering, number of tubers per plant, weight of each tuber, yield per plant and yield (ton ha^{-1}) of potato at Chilime, Rasuwa, 2019

Treatments	Days for 50% Flowering	Number of Tubers per Plant	Weight of Each Tuber (gram)	Yield (mt ha^{-1})
Varieties				
Janak Dev	61.17[c]	5.75[c]	88.03[a]	23.90[b]
KhumalUjjwal	71.83[b]	8.91[ab]	58.87[b]	24.95[b]
Khumal Seto-1	71.83[b]	9.16[a]	60.71[b]	25.87[b]
KufriJyoti	73.17[a]	7.41[b]	107.70[a]	37.10[a]
SEm (±)	0.31	0.51	8.38	1.91
LSD (=0.05)	0.95***	1.57***	25.43**	5.81***
Fertilizer				
RDF	69.75	8.00	88.90	31.70
FYM	69.25	7.62	68.80	24.20
SEm (±)	0.22	0.36	5.93	1.35
LSD (=0.05)	NS	NS	17.98*	4.10***
CV (%)	1.10	16.20	26.00	16.80
Grand Mean	69.50	7.81	78.80	27.96

Note: The treatment mean followed by common letters in same column does not significantly differ from each other based on DMRT at 5 % level of significance.

Number of tubers per plant

The number of tubers per plant was found significant among varieties (Table 2). The highest number of tubers was recorded in Khumal-Seto-1 (9.167) followed by Khumal-Ujjwal (8.917) and Kufri-Jyoti (7.417). Janak-Dev had the lowest (5.75) number of tubers per plant. From the research results, number of tubers per plant depends on number of main stems per plant; variation on tuber numbers might also be genetic.

Effect of fertilizer on number of tubers per plant was found non-significant. Plants treated with inorganic and organic fertilizer had 8.00 and 7.62 tubers respectively. Kumar and Wareing (1972) found that nitrogen increased Gibberellins biosynthesis which regulated number of stolons and ultimately the number of tubers increased.In

another study, Sharma and Arora(1987) reported no relationship between nitrogen and tuber numbers. Phosphorus also did not influence number of tubers. In relation to nutrition, tuber number is not an important for yield component (Lynch and Rowberry, 1997). There is inverse relation between number of tubers and average tuber weight (De La Morena et al., 1994).

Weight of each tuber

Significant effect was observed on weight of each tuber (Table 2). The highest (107.7 gm) tuber weight was recorded in Kufri Jyoti and which was on par with Janak Dev (88.03 gm). Khumal Ujjwal had the lowest (58.87 gm) individual tuber weight which was statistically similar with Khumal Seto-1 (60.71 gm).

Fertilizers showed significant difference on weight of each tuber. Weight of tuber of plants treated with inorganic and organic fertilizer was of 88.90 and 68.80 gram respectively.

Plants treated with inorganic fertilizer had sufficient amounts of nitrogen, phosphorus and potassium which caused luxuriant growth, more foliage, higher supply of photosynthates ultimately bigger tubers were produced (Patricia and Bansal, 1999). Nitrogen and phosphorus maximize the tuber growth (De La Morena et al., 1994). It was found that nitrogen, phosphorus and potassium supplied by inorganic fertilizer increases the tuber size. Fertilizer application can increase dry matter content, protein content of potato tubers (Zelalem et al., 2009).

Yield (mt ha^{-1})

Varieties had highly significant effect on yield (mt ha^{-1}) (Table 2). Kufri Jyoti had the highest (37.1 mt ha^{-1}) yield. Khumal Seto-1, Khumal Ujjwal and Janak Dev had statistically similar yield i.e. 25.87, 24.95 and 23.90 mt ha^{-1} respectively.

Effect of fertilizers was highly significant on yield per hectare. The yield from inorganic and organic fertilization was 31.70 and 24.20 mt ha^{-1} respectively. Sufficient supply of nitrogen, phosphorus and potassium from inorganic sources of fertilizer increased number of tubers, weight of each tuber and yield per plant. Hence the yield per hectare was found higher in inorganic fertilizer application. (Kleinkopf et al. 1981) found strong relationship between yield and fertilization.

Interaction effect of varieties and fertilizers on plant height and canopy diameter

Table 3. Interaction effect of varieties and fertilizer on plant height and canopy diameter of potato at Chilime, Rasuwa, 2019

Treatments	Plant Height (cm)	
Variety × Fertilizer		
	45 DAS	45 DAS
V_1FYM	14.33[a]	60.67[ab]
V_1RDF	5.75[c]	63.25[a]
V_2FYM	9.66[b]	49.42[e]
V_2RDF	6.00[c]	60.60[ab]
V_3FYM	8.00[bc]	50.30[de]
V_3RDF	7.00[bc]	54.78[cd]
V_4FYM	9.66[b]	57.50[bc]
V_4RDF	8.33[bc]	60.17[ab]
SEm±	1.02	1.56
LSD(0.05)	3.11*	4.73*

Note: The treatment mean followed by common letters in same column does not significantly differ from each other based on DMRT at 5 % level of significance.

The interaction effect of varieties and fertilizers was non-significant at 75, 90 and 105 DAS but significant at 45 and 60 DAS (Table 3). At 45 DAS and 60 DAS, highest plant heights were recorded in Janak Dev planted with organic fertilizer (14.33 and 24.58 cm respectively) whereas Janak Dev with inorganic fertilizer had lowest height (5.750 cm) at 45 DAS. Height of other plants was similar at 60 DAS.

Interaction effect of varieties and fertilizers on plant canopy diameter was found significant only at 90 days after sowing. The largest (63.25 cm) canopy diameter was in Janak-Dev treated with inorganic fertilizer followed by Janak-Dev with organic, Khumal-Ujjwal with inorganic and Kufri-Jyoti with inorganic fertilizer with diameter 60.67, 60.60 and 60.17 cm respectively. The least (49.20 cm) canopy diameter was found in Khumal-Ujjwal with organic. There was no interaction effect in other parameters.

CONCLUSION

The maximum weight of each tuber, yield per plant and yield per hectare were obtained from Kufri-Jyoti. These parameters were the highest with the usage of chemical fertilizers. The field experiment showed that Kufri-Jyoti with recommended dose of chemical fertilizer was appropriate to get optimum yield under Chilime condition.

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