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Effects of organic and inorganic fertilizers on growth and yield of potato (*Solanum tuberosum* L.) in central plan zone of Uttar

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Abstract
Field experiment was conducted with potato (*Solanum tuberosum*) during winter (rabi) seasons of 2022-23 to study the effect of different Organic and Inorganic Fertilizers on Growth, Yield and Quality of Potato (*Solanum tuberosum* L.) in Central Plan Zone of Uttar. The experiment varieties, Kufri Bahar and nutrient sources *viz*. FYM + recommended dose of NPK (150:100:100 kg/ha N, P2 O5, K2 O respectively) It was observed highest plant height (24.98 cm) in T_4 recommended dose of fertilizer 100% RDF through inorganic and organic fertilizer(100% RDF + FYM @ 15tha^{-1}), total tuber yield per hectare as influenced by organic and inorganic fertilizers practice showed significant difference and the mean values were observed to be in the range of 140.80 to 380.33 q ha^{-1} (Table 1). The highest tuber yield per hectare (380.33 q ha^{-1}) was recorded with T_4 100% RDF + FYM @ 15tha^{-1} followed by T_7 75% RDF + FYM @ 15tha^{-1} (340.66 qha^{-1}). The lowest total tuber yield per hectare was recorded with T_8 (140.80 q ha^{-1}). Recommended dose of NPK showed the best performance in terms of growth and yield parameters as compared to organic sources of nutrients. FYM @ 15 tonnes/ha along 100% RDF) recorded maximum soil fertility build-up after harvest of the crop and also helped to achieve required processing qualities of potato tuber. It was concluded that Kufri Bahar Varietie were suitable processing cultivars as they met all the necessary requirements and as well as integrated nutrient management using both manures and fertilizers gave high level of guarantee with improved quality potato production.

Keywords: Potato, organic and inorganic rabi, *Solanum tuberosum* L., FYM

Introduction
Potato (*Solanum tuberosum* L.) is the fourth most important food crop in the world after rice, maize and wheat in terms of human consumption (Karam *et al*., 2009; Kandil *et al*., 2011) [2, 3]. The quantity produced yearly exceeds 300 million metric tons and more than a billion people worldwide consume potato which is rich in carbohydrates, protein, vitamins, dietary fibers, simple sugars and minerals (CIP, 2010; FAO, 2008) [4, 5]. In India, during 2018-19, vegetable crops were under cultivation over an area of 10.07 million hectare with a production and productivity of 183.17million MT and 18.2 MT/ha, respectively (Anonymous, 2019a) [1]. In order to achieve high yield, potato requires cool weather, reasonable amount of nitrogen (N), phosphorus (P) and potassium (K) in the soil. Production in India is constrained by poor farming practices, high cost of seeds, diseases, pests and poor soil fertility management.

This study is focused on soil fertility management using organic manure and inorganic fertilizers since little has been done to determine the most appropriate combination rate for optimum potato yield. As reported by Monirul *et al*. (2013) [6], variation in the rate of application of organic and inorganic fertilizers could influence the yield of potato. Organic manures and their extracts have been used to improve soil fertility and in combating pests and diseases (Abbasi *et al*., 2002; Barker and Bryson 2006; Khadem, *et al*., 2010; Litterick *et al*., 2004) [7, 8, 9, 10]. Organic manures and composts have also been found to have a direct anti disease effect by stimulating competing micro-organisms and also by inducing resistance to plant diseases (Brinton *et al*., 1996) [11].

However, there are other contradicting evidences indicating the reverse impact of using these sources (Chauhan *et al*., 2000) [12]. The use of fertilizers and manure to enhance soil fertility and hence crop yield improvement is a traditional method that has been in use for a very long time. On the other hand the use of compost on agricultural land has been widely accepted for sustainable agriculture (Perez *et al*., 2007; Hargreaves *et al*., 2008) [14, 15]. Positive role of compost application has been reported in many crops (Marcote *et al*., 2001) [16]. The application of compost increase microbial activity, nitrogen concentration and grain yield (Tejada *et al*., 2003) [17]. Phosphorus is the second most important macro nutrient after nitrogen that plays significant role in physiological and biochemical reactions such as photosynthesis and transfer characteristics (Mehrvarz *et al*., 2008) [13]. Phosphorus fertilizers and manure in the soil increase phosphorus uptake by plants, through favoring production of carbonic acid, the acid that increases solubility of phosphate compounds in calcareous soils (Chien, 2003) [18]. Fertilizer application has important effects on the quality and yield of potatoes (Leytem and Westermann, 2005) [19]. Potato is highly responsive to N fertilization and N is usually the most limiting essential nutrient for potatoes growth, especially on sandy soils (Errebhi *et al*., 1998) [20]. Nitrogen supply also plays an important role in the balance between vegetative and reproductive growth for potato. Many previous studies have shown that N fertilizer applications can increase dry matter content, protein content of potato tubers, total and/or marketable tuber yield (Zebarth *et al*., 2004) [2]. Nitrogen fertilization has been reported to increase the average fresh tuber, plant height, leaf number and tuber weight per plant (Kandil., 2011; Semiha., 2009) [3]. The purpose of the present study was to determine the effects of animal manure and inorganic fertilizer on potato production.

Materials and Methods

Field experiment was conducted during winter (rabi) seasons of 2021-22 at The experiment was conducted at Agricultural Research Farm, Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur (U.P.). The physico-chemical analysis of the soil was done by collecting soil samples from a depth of 0–30 cm. The soil contained 305, 15 and

221 kg/ha available N, P2O5 and K2O, respectively. The experiment was conducted in randomized block design (RBD), replicated thrice, with varieties, Kufri Bahar in the main plots and two different sources of nutrients, *viz* FYM + recommended dose of fertilizers (NPK, i.e. 180:100:100 kg/ha) N, P2O5, K2O. Each year a basal dose of half of N, full P2O5 and K2O were applied through urea, respectively and rest half of N was top dressed at 30 days after planting. Farmyard manure, as per the treatments were applied as basal in years.

The experimental details is as follows: T_1 – 100% RDF (150:100:100), T_2- 100% RDF + FYM @ 5tha^{-1} T_3-100% RDF + FYM @ 10tha^{-1}, T_4- 100% RDF + FYM @ 15tha^{-1} T_5 – 75% RDF + FYM @ 5tha^{-1} T_6 -75% RDF + FYM @ 10tha^{-1}, T_7- 75% RDF + FYM @ 15tha^{-1}, T_8-control. Observations on growth and yield parameters were recorded and subjected to statistical analysis. The procedure for recording the observations are mentioned below.

Results and Discussion

Growth parameters Plant height

The analysis of variance of plant height showed highly significant differences for the combination of organic and inorganic fertilizers.

The data on plant height of potato (cm) at 30, 60 and 90 DAP are presented in Table 2. The perusal of data indicated significant differences among the different treatments at all growth stages except 30 DAP. The plant height at 30 DAP was observed to beingthe range of 16.45–24.98 cm. It was observed highest (24.98 cm) in T_4 recommended dose of fertilizer 100% RDF through inorganic and organic fertilizer (100% RDF + FYM @ 15tha^{-1}) followed by T_7 75% RDF + FYM @ 15tha^{-1} (22.98 cm) and lowest plant height at 30DAP was observed in T_1 control (16.45 cm). At 60 and 90 DAP, among the treatments significantly higher plant height was observed in T_4 100% RDF through inorganic and organic fertilizer (100% RDF+ FYM @ 15tha^{-1}) (45.16 cm and 47.49 cm, respectively). The plant height (47.49 cm) at 60 DAP in T_4 100% RDF through inorganic and organic fertilizer (100% RDF + FYM @ 15tha^{-1}) is followed by T_7 75% RDF through inorganic and organic fertilizer (75% RDF + FYM @ 15tha^{-1}) (44.82 cm) lowest was observed in T_8control (38.65 cm). The plant height (47.49 cm) at 90 DAP in T_4 is followed by T_7 (45.91 cm) and the lowest plant height was observed with T_8 (40.61cm). However, when combined with 100% RDF either alone or in combination with 5 t FYM there was an increase in plant height. The lower plant height with sole application of FYM might be due to their slow decomposition thus resulting in less availability of nutrients for the plant uptake. Generally it was observed that treatments that received both organic and inorganic fertilizer produced plants with more height as compared to plants in unfertilized plot. The increase in plant height in the presence of inorganic fertilizer might be due to better availability of nutrients and the inorganic fertilizer in combined application with FYM might have enhanced the decomposition of organic sources thus the increased supply of nutrients for increasing the cell division and elongation. The current experiment result corroborates the findings of Gonzalez *et al*. (2001) [17] who reported that organic manure and inorganic fertilizer supplied all the essential nutrients at seedling stage resulting in an increase of measured variables like plant height and also reported the combined effect of organic fertilizer and inorganic fertilizer on the plant height was significant.

Table 1: Effect of organic and inorganic sources of nutrients on plant height at 30, 60 and 90 days after sowing

S. No.	Treatments	Plant height (cm)		
		30 DAP	60 DAP	90 DAP
T_1	100% RDF (N:P:K=150:100:100)	17.36	37.86	42.55
T_2	100% RDF + FYM @ 5tha^{-1}	20.65	42.98	43.10
T_3	100% RDF + FYM @ 10tha^{-1}	22.19	44.11	45.80
T_4	100% RDF + FYM @ 15tha^{-1}	24.98	45.16	47.49
T_5	75% RDF + FYM @ 5tha^{-1}	21.64	42.71	43.13
T_6	75% RDF + FYM @ 10tha^{-1}	22.98	43.19	44.68
T_7	75% RDF + FYM @ 15tha^{-1}	23.11	44.82	45.91
T_8	Control	16.45	38.65	40.61
	S.Em±	0.79	1.02	1.45
	C.D. at 5%	2.40	2.99	4.15

Leaf area index: The data on leaf area plant-1 at different growth stages as influenced by different organic and inorganic fertilizer in potato are presented in Table 2.

Table 2: Effect of organic and inorganic sources of nutrients on Leaf area index at flower initiation

S. No.	Treatments	Leaf area index at flower initiation
T_1	100% RDF (150:100:100)	1179
T_2	100% RDF + FYM @ 5tha^{-1}	1285
T_3	100% RDF + FYM @ 10tha^{-1}	1420
T_4	100% RDF + FYM @ 15tha^{-1}	1532
T_5	75% RDF + FYM @ 5tha^{-1}	1201
T_6	75% RDF + FYM @ 10tha^{-1}	1398
T_7	75% RDF + FYM @ 15tha^{-1}	1467
T_8	Control	1013
	S.Em±	0.52
	C.D. at 5%	2.03

At flower initiation, application of 100% recommended dose of fertilizer + FYM @ 15tha^{-1}ha^{-1} recorded significantly higher leaf area plant-1 (1532 cm2) and which was close to treatment with application of 75% RDF + FYM @ 10tha^{-1}, followed by 100% RDF + FYM @ 10tha^{-1} (1467 cm2). Significantly lower leaf area plant-1 was recorded in treatment with application of 100% RDF (150:100:100), followed by 75% RDF + FYM @ 5tha^{-1} at 30, 45, 60 DAP (1201 cm2) This increase in leaf area index might be due more availability and up take of nutrients. Furthermore, the results of the present study could probably be attributed to the beneficial effect integrated fertilizer use and the macro as well as micro nutrients supplied through FYM and increased availability of plant nutrients. The result of the current experiment corroborates the finding of who reported the integrated nutrient management practices significantly influenced leaf area index.

Dry matter accumulation (g plant-1) at 30, 60, 90 DAP and at harvest: Data pertaining to dry matter accumulation plant-1 (g) at 30, 60 and 90 DAP and at harvest of potato as influenced by organic and inorganic fertilizers is given in table 3.

Table 3: Effect of organic and inorganic sources of nutrients on Dry matter accumulation (g plant^{-1})

S. No.	Treatments	Dry matter accumulation (g plant^{-1})			
		30 DAP	60 DAP	90 DAP	at harvest
T_1	100% RDF(N:P:K=150:100:100)	17.36	37.86	42.55	45.70
T_2	100% RDF + FYM @ 5tha^{-1}	20.65	42.98	43.10	48.32
T_3	100% RDF + FYM @ 10tha^{-1}	22.19	44.11	45.80	50.97
T_4	100% RDF + FYM @ 15tha^{-1}	24.98	45.16	47.49	52.40
T_5	75% RDF + FYM @ 5tha^{-1}	21.64	42.71	43.13	46.88
T_6	75% RDF + FYM @ 10tha^{-1}	22.98	43.19	44.68	47.13
T_7	75% RDF + FYM @ 15tha^{-1}	23.11	44.82	45.31	49.48
T_8	Control	16.45	38.65	40.61	42.71
	S.Em±	0.72	1.18	1.83	2.29
	C.D. at 5%	2.16	3.18	4.88	5.93

It was also revealed from the data that significantly the highest accumulation of dry matter was recorded in treatment T_4 [100% RDF through inorganic and organic fertilizer (100% RDF + FYM @ 15tha^{-1})] i.e.25.34, 30.14 and 39.12 and 47.85 at 30, 60 and 90 DAP and at harvest, respectively. Not only that, but at all the growth stages it was found at par with treatment T_4. On the other hand, significantly the lowest accumulation of dry matter plant-1 was observed in treatment T_8 which remained 17.32, 17.23 and 21.75 and 26.34 g at 30and 60 DAP and at harvest, respectively.

Yield attributes and yield

Number of tubers per plant

The data concerning to number of tubers plant-1 as affected by organic and inorganic fertilizers are presented in table- 4

and depicted graphically in Results indicated that the effect organic and inorganic fertilizers on number of tubers plant-1 was found significant and significantly higher number of tubers planT_1 (7.65) was recorded under treatment T_4 [100% RDF + FYM @ 15tha^{-1}], followed by with treatment T_3 (100% RDF + FYM @ 10tha^{-1}) However, significantly lower number of tuber plant-1 (3.71) was observed in control.

Table 4: Effect of organic and inorganic sources of nutrients on number of tubers per plant and weight of tubers per plant (g)

S. No.	Treatments	Number of tubers per plant.	Weight of tubers per plant (g)
T_1	100% RDF (150:100:100)	4.23	110.70
T_2	100% RDF + FYM @ 5tha^{-1}	5.89	134.65
T_3	100% RDF + FYM @ 10tha^{-1}	6.42	142.30
T_4	100% RDF + FYM @ 15tha^{-1}	7.65	160.21
T_5	75% RDF + FYM @ 5tha^{-1}	5.34	130.78
T_6	75% RDF + FYM @ 10tha^{-1}	5.79	130.16
T_7	75% RDF + FYM @ 15tha^{-1}	6.11	138.43
T_8	Control	3.71	98.20
	S.Em±	0.12	4.32
	C.D. at 5%	0.34	9.48

Weight of tubers per plant (g)

Higher tuber weight (160.21g plant-1) was recorded with application of 100% RDF + FYM @ 15tha^{-1} and lower tuber weight (110.70g plant-1) was recorded in treatment with application of 100% RDF (150:100:100), followed by 75% RDF + FYM @ 5tha^{-1} (130.78).

Potato tuber yield (q ha^{-1})

The data on total tuber yield per hectare as influenced by organic and inorganic fertilizers practice showed significant difference and the mean values were observed to be in the range of140.80 to 380.33 q ha^{-1}(Table 5). The highest tuber yield per hectare (380.33 q ha^{-1}) was recorded with T_4 100% RDF + FYM @ 15tha^{-1} followed by T_7 75% RDF + FYM @ 15tha^{-1} (340.66 qha^{-1}). The lowest total tuber yield per hectare was recorded with T_8 (140.80 q ha^{-1}).

Table 5: Effect of organic and inorganic sources of nutrients on potato tuber yield (q ha^{-1})

S. No.	Treatments	Potato tuber yield (q ha^{-1})
T_1	100% RDF (150:100:100)	240.99
T_2	100% RDF + FYM @ 5tha^{-1}	260.00
T_3	100% RDF + FYM @ 10tha^{-1}	290.60
T_4	100% RDF + FYM @ 15tha^{-1}	380.33
T_5	75% RDF + FYM @ 5tha^{-1}	266.50
T_6	75% RDF + FYM @ 10tha^{-1}	300.00
T_7	75% RDF + FYM @ 15tha^{-1}	340.66
T_8	Control	140.80
	S.Em ±	12.74
	C.D. at 5%	35.73

Conclusion and Recommendation

Field observations have shown high crop performance and yield differences of different crops on organically managed farmer's field and research site. Our study results also revealed that 15 ton FYM application increased potato tuber yield approx by three and two fold over untreated control and NP treatments. It was observed that NPK fertilizers applied significantly influenced potato yield but combined application of 15 t ha^{-1} FYM and NPK is superior to all other treatments and profitable. Seed bed preparation method results showed that hoe plough once or reduced tillage practice is sufficient for potato production without yield reduction. Hence, the combined use of NPK and FYM and hoe plough once could be recommended as important nutrient management and sustainable potato production practice in Alisols of Chencha. But further research is needed to verify different combination of organic and inorganic fertilizers.

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