

Influence of INM Practices with *In-Situ* Green Manuring on Yield and Nutrient Uptake by Potato (*Solanum tuberosum* L.)

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Abstract A field experiment was done to assess the influence of INM practices with *in-situ* green manuring on growth and yield of potato during *kharif* of 2013. The experiment was laid out in a factorial randomized complete block design (FRCBD) with three replications and twelve treatment combinations including 2 fertilizer levels (75 and 100% RDF), 3 compost levels (0, 12.5 and 25 t ha⁻¹ compost) and *in-situ* green manuring with sunhemp and cowpea. The investigation revealed that among treatment combinations, 100% RDF + 25 t ha⁻¹ compost + *in-situ* green manuring with cowpea recorded higher tuber weight (207.1 g plant⁻¹), number of tubers (7.2 plant⁻¹) and tuber yield (17.26 t ha⁻¹) at harvest. The same treatment also recorded the higher total nutrient uptake (117.1, 27.2 and 145.3 kg of N, P₂O₅ and K₂O ha⁻¹). Application 75% recommended dose of NPK

with 12.5 t ha⁻¹ compost and *in-situ* green manuring with cowpea recorded similar results but less reduction in the tuber yield and it is feasible for the potato by saving 25% fertilizer and 50% compost.

Keywords INM, *In-situ* green manuring, Yield, Nutrient uptake, Potato.

Introduction

Organic fertilizers are indispensable for vegetable cultivation in the present agricultural scenario due to the often low organic matter content of the arable land [1]. Soil and fertility management requires management of organic matter decomposition, synchronizing N availability with crop demand and preventing excessive N release and leaching, which are correspondingly a challenge. Potato is an arable crop prefers loose and friable soil for its normal growth and development. Economic part (tubers) of the crop developing in the soil, so maintenance of arable / friable soil condition is essential even upto maturity of the crop. Application of organic manures in huge quantities is essential to ensure optimal soil physical condition. But in the present scenario of reduced animal population, deforestation, availability of organic manure has reduced considerably.

Relatively higher rates of nutrients (especially N) required for potato production, coupled with the susceptibility of nitrate leaching by rainfall and irri-

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gation has increased concern about groundwater pollution [2]. Nitrogen is critically important for canopy development, tuber initiation (TI) and yield of potato [3]. Insufficient N supply results in lower tuber yields and size, while excess N can promote abundant haulm growth, delays TI and crop maturation and reduce tuber yield and quality [4]. Synthetic fertilizer N can easily be lost from the crop system, with consequent economic and environmental costs. In order to address above mentioned challenges requires a set of management practices to synchronize between N availability in the soil and N uptake by the potato root to maximize yield and minimize N loss, to conserve soil resources, maintain or enhance productivity and to reduce farmers' reliance on costly chemical fertilizers.

In view of this as an alternative inclusion of green manures in rotation with INM practices is only possible way. Therefore, in designing INM practices for improved long-term sustainability, continued research and grower experimentation are needed to optimize regionally relevant combinations of crop rotations including green manure crops and other organic sources. Legumes are commonly used as green manures because of their ability to fix N from the atmosphere and it slowly releases nutrients after incorporation into the soil thus potentially contribute appreciable amounts of N to the soil. In general, where N supply to the crop from soil and green manures alone averages 100–130 kg N ha⁻¹ [5]. N supplied to soil from legumes will likely reduce or possibly replace the need for fertilizer N. In addition to the N added to the soil, green manure legumes may increase organic matter, lower soil bulk density, increase soil microbiological biomass, increase infiltration of water [6], reduce the crop pathogens, help to control weeds and prevent the soil erosion.

Potato cultivation is one of the major sources of income to the local farmers in the study area. Nutrient management in potato production in this area is highly intensive, relying heavily on chemical fertilizers. With the above background, the present investigation was carried out to assess the influence of INM practices with *in-situ* green manuring on growth and yield of potato.

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Materials and Methods

The experiment was conducted at the college of agriculture, Hassan, UAS, Bangalore, Karnataka in *kharif* of 2013. The soil was neutral in reaction (pH 7.08) and organic carbon content (0.48%) was low. The soil test results of the experimental site reveal that soil is medium in nitrogen (330.5 kg ha⁻¹), phosphorus (53.3 kg ha⁻¹) and potassium (215.0 kg ha⁻¹). During the cropping season (June 2013–September 2013), a total of 459.5 mm rainfall was received. The field experiment was laid out in a factorial randomized complete block design (RCBD) with three replications. There were 12 treatment combinations comprising of 2 fertilizer levels (75 and 100% RDF), 3 compost levels (0, 12.5 and 25 t ha⁻¹ compost) and *in-situ* green manuring with sunhemp and cowpea were included in this study. The treatment combinations were T₁ : 75% recommended NPK + control + *in-situ* green manuring with sunhemp, T₂ : 75% recommended NPK + control + *in-situ* green manuring with cowpea, T₃ : 75% recommended NPK + 12.5 t ha⁻¹ compost + *in-situ* green manuring with sunhemp, T₄ : 75% recommended NPK + 12.5 t ha⁻¹ compost + *in-situ* green manuring with cowpea, T₅ : 75% recommended NPK + 25 t ha⁻¹ compost + *in-situ* green manuring with sunhemp, T₆ : 75% recommended NPK + 25 t ha⁻¹ compost + *in-situ* green manuring with cowpea, T₇ : 100% recommended NPK + control + *in-situ* green manuring with sunhemp, T₈ : 100% recommended NPK + control + *in-situ* green manuring with cowpea, T₉ : 100% recommended NPK + 12.5 t ha⁻¹ compost + *in-situ* green manuring with sunhemp, T₁₀ : 100% recommended NPK + 12.5 t ha⁻¹ compost + *in-situ* green manuring with cowpea, T₁₁ : 100% recommended NPK + 25 t ha⁻¹ compost + *in-situ* green manuring with sunhemp, T₁₂ : 100% recommended NPK + 25 t ha⁻¹ compost + *in-situ* green manuring with cowpea.

After the harvest of fodder maize grown during *rabi* season of 2012–2013 the land was prepared by using disc plough followed by passing cultivator to break the clods and to collect weeds and stubbles.

Table 1. Yield parameters as influenced by INM practices with *in-situ* green manuring in potato. F₁-75% RDF ; F₂-100% RDF ; C₀-Control ; C₁-12.5 t ha⁻¹ compost ; C₂-25 t ha⁻¹ compost. G₁-*In-situ* green manuring with sunhemp ; G₂-*In situ* green manuring with cowpea. NS-Non significant.

Treatments	Tuber weight plant ⁻¹ (g)	No. of tubers plant ⁻¹	Tuber grading (t ha ⁻¹)				Tuber yield (t ha ⁻¹)
			D <25 g	C 25-50 g	B 50-75 g	A >75 g	
Fertilizer level (F)							
F ₁	159.0	5.7	3.70	3.72	3.20	2.84	13.26
F ₂	171.5	6.1	3.55	4.10	3.58	3.08	14.29
SEm±	1.20	0.07	0.04	0.08	0.05	0.04	0.10
CD @ 5%	3.48	0.21	0.11	0.23	0.15	0.13	0.29
Compost level (C)							
C ₀	135.6	5.3	3.78	2.99	2.74	2.09	11.30
C ₁	170.6	5.9	3.61	4.06	3.38	3.18	14.22
C ₂	189.6	6.4	3.47	4.69	4.05	3.61	15.81
SEm±	1.47	0.09	0.05	0.10	0.06	0.05	0.12
CD @ 5%	4.26	0.26	0.14	0.28	0.19	0.15	0.35
Green manures (G)							
G ₁	154.9	5.6	3.62	3.61	3.20	2.68	12.91
G ₂	175.6	6.1	3.63	4.22	3.57	3.23	14.64
SEm±	1.20	0.07	0.04	0.08	0.05	0.04	0.10
CD @ 5%	3.48	0.21	NS	0.23	0.15	0.13	0.29
Interaction (F×C)							
SEm±	2.08	0.13	0.07	0.14	0.09	0.08	0.17
CD @ 5%	6.03	0.36	0.20	0.40	0.26	NS	0.50
Interaction (F × G)							
SEm±	1.70	0.10	0.06	0.11	0.07	0.06	0.14
CD @ 5%	4.92	0.30	NS	0.33	0.21	0.18	0.41
Interaction (C × G)							
SEm±	2.08	0.13	0.07	0.14	0.09	0.08	0.17
CD @ 5%	6.03	0.36	0.20	NS	0.26	0.22	0.503
Interaction (F×C×G)							
F ₁ ×C ₀ ×G ₁	128.0	4.8	3.64	2.41	3.05	1.57	10.67
F ₁ ×C ₀ ×G ₂	133.8	5.4	3.77	3.02	2.32	2.05	11.16
F ₁ ×C ₁ ×G ₁	142.4	5.7	3.42	3.31	2.73	2.41	11.87
F ₁ ×C ₁ ×G ₂	198.9	6.1	3.78	4.72	4.08	3.85	16.58
F ₁ ×C ₂ ×G ₁	158.7	5.7	3.80	3.85	2.67	2.91	13.23
F ₁ ×C ₂ ×G ₂	201.6	6.4	3.50	4.71	4.06	3.93	16.80
F ₂ ×C ₀ ×G ₁	139.8	5.6	3.87	3.01	2.57	2.20	11.65
F ₂ ×C ₀ ×G ₂	140.6	5.6	3.53	3.22	2.72	2.25	11.72
F ₂ ×C ₁ ×G ₁	162.3	5.8	3.52	3.89	3.16	2.96	13.53
F ₂ ×C ₁ ×G ₂	180.7	6.0	3.71	4.31	3.56	3.48	15.06
F ₂ ×C ₂ ×G ₁	203.1	6.3	3.15	4.87	4.76	3.75	16.93
F ₂ ×C ₂ ×G ₂	207.1	7.2	3.43	5.31	4.69	3.83	17.26
SEm±	2.94	0.18	0.10	0.19	0.13	0.11	0.24
CD @ 5%	NS	0.52	0.28	NS	0.37	0.31	NS

Finally the land was levelled using a bullock drawn leveller. The plot size was 3.6 m × 3.2 m (11.52 m²). *In-*

situ green manure crops (cowpea and sunhemp) were sown in their respective plots and incorporated at 45

Table 2. Nutrient uptake as influenced by INM practices with *in-situ* green manuring in potato. F₁-75% RDF ; F₂-100% RDF ; C₀-Control ; C₁-12.5 t ha⁻¹ compost ; C₂-25 t ha⁻¹ compost. G₁-*In-situ* green manuring with sunhemp ; G₂-*In situ* green manuring with cowpea. NS-Non significant.

Treatments	Tubers (kg ha ⁻¹)			Haulms (kg ha ⁻¹)			Total (kg ha ⁻¹)		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Fertilizer level (F)									
F ₁	58.2	13.2	68.9	2.8	0.7	6.3	61.1	13.9	75.3
F ₂	72.9	16.6	86.3	3.6	0.8	8.0	76.5	17.5	94.3
SEm±	1.94	0.45	2.29	0.10	0.03	0.17	1.95	0.46	2.30
CD @ 5%	5.68	1.32	6.72	0.27	0.8	0.50	5.72	1.34	6.73
Compost level (C)									
C ₀	32.7	7.5	38.7	1.8	0.4	4.2	34.5	7.96	42.9
C ₁	70.5	15.6	83.4	3.2	0.8	7.2	73.7	16.4	90.7
C ₂	93.5	21.6	110.7	4.6	1.1	10.1	98.1	22.8	120.8
SEm±	2.37	0.55	2.81	0.12	0.04	0.21	2.39	0.56	2.81
CD @ 5%	6.96	1.61	8.23	0.34	0.10	0.61	7.01	1.64	8.24
Green manures (G)									
G ₁	56.7	12.6	67.1	2.8	0.7	6.3	59.5	13.3	73.4
G ₂	74.5	17.2	88.1	3.6	0.8	8.0	78.1	18.1	96.2
SEm±	1.94	0.45	2.29	0.10	0.03	0.17	1.95	0.46	2.30
CD @ 5%	5.68	1.32	6.72	0.27	0.08	0.50	5.72	1.34	6.73
Interaction (F×C)									
SEm±	3.36	0.78	3.97	0.16	0.05	0.29	3.38	0.79	3.98
CD @ 5%	9.85	2.28	11.65	0.48	0.14	0.86	9.92	2.32	11.66
Interaction (F× G)									
SEm±	2.74	0.64	3.24	0.13	0.04	0.24	2.76	0.65	3.25
CD @ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (C×G)									
SEm±	3.36	0.78	3.97	0.16	0.05	0.29	3.38	0.79	3.98
CD @ 5%	NS	2.28	NS	0.48	NS	0.86	9.92	2.32	11.66
Interaction (F×C×G)									
F ₁ ×C ₀ ×G ₁	22.3	4.9	26.4	1.4	0.2	3.2	23.8	5.2	29.6
F ₁ ×C ₀ ×G ₂	27.8	6.9	32.9	1.6	0.3	3.7	29.5	7.3	36.7
F ₁ ×C ₁ ×G ₁	52.6	10.9	62.2	2.7	0.6	6.2	55.3	11.5	68.4
F ₁ ×C ₁ ×G ₂	85.9	19.1	101.6	3.7	0.9	8.5	89.6	20.1	110.2
F ₁ ×C ₂ ×G ₁	67.1	15.0	79.3	2.9	0.7	6.5	70.0	15.7	85.8
F ₁ ×C ₂ ×G ₂	93.9	22.5	111.1	4.4	1.1	9.8	98.4	23.6	121.0
F ₂ ×C ₀ ×G ₁	34.5	7.8	40.8	1.9	0.4	4.4	36.4	8.2	45.2
F ₂ ×C ₀ ×G ₂	46.2	10.4	54.7	2.3	0.5	5.5	48.5	10.9	60.2
F ₂ ×C ₁ ×G ₁	62.3	13.6	73.7	2.9	0.7	6.5	65.2	14.3	80.2
F ₂ ×C ₁ ×G ₂	81.4	18.6	96.3	3.4	0.8	7.6	84.8	19.5	103.9
F ₂ ×C ₂ ×G ₁	101.4	23.3	120.0	5.0	1.2	10.9	106.5	24.6	131.0
F ₂ ×C ₂ ×G ₂	111.7	25.8	132.2	6.0	1.4	13.1	117.7	27.2	145.3
SEm±	4.75	1.10	5.62	0.23	0.07	0.42	4.78	1.12	5.62
CD @ 6%	NS	NS	NS	NS	NS	NS	NS	NS	NS

DAS (on an average cowpea and sunhemp added 22.5 and 13.7 t ha⁻¹ biomass respectively). Calculated quantities of compost were incorporated into the soil in each plot 15 days before planting of potato for

proper decomposition according to the treatments.

Seed tubers of Kufri Jyothi weighing approximately 30—40 grams were dipped in a solution of

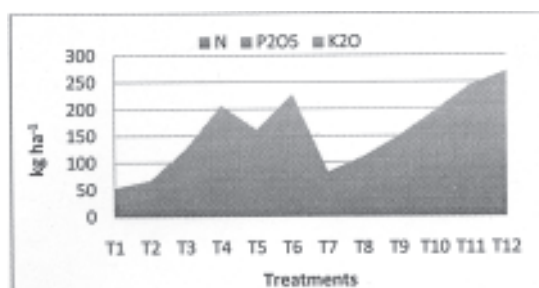


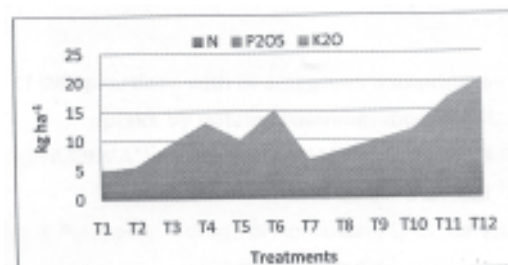
Fig. 1. (a)

dithane M-45 (2 g in one liter of water) for 20 minutes and dried in shade before planting to prevent the decay of seed tubers. After bringing the soil to fine tilth, furrows at 60 cm apart were formed and calculated quantities of recommended dose of 125:100:125 kg N, P₂O₅ and K₂O ha⁻¹ were applied in the form of urea, diammonium phosphate and muriate of potash respectively as per the treatments to the each plot and mixed well into the soil. The tubers were planted half way the ridge at a distance of 20 cm. Fifty percent of the recommended nitrogen was applied at the time of planting and remaining fifty percent was applied four weeks after planting as top dressing. Common irrigation was given to all the treatments during the dry spell using portable sprinkler. Totally 4 irrigations were scheduled during the cropping period.

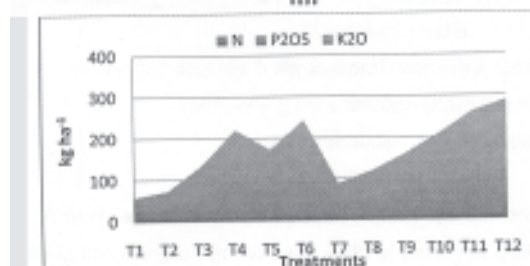
Five plants were randomly selected in net plot and labelled. Observations on growth and yield parameters were recorded using these plants. Tubers obtained from the five plants selected at random were graded after harvest as large sized : A-grade (>75 g), medium sized: B-grade (50—75 g), small sized: C-grade (25—50 g) and very small sized: D-grade (<25 g) based on weight of tubers and finally total yield was calculated. N, P and K uptake was calculated for each treatment separately using the following formula.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Percent of nutrient concentration}}{100} \times \text{dry matter (kg ha}^{-1}\text{)}$$

The data pertaining to the experiment were sub-



(b)



(c)

Fig. 1 (a, b, c). Influence of INM practices on nutrient uptake by tubers (a) haulms (b) and total (c) nutrient uptake in potato.

jected to statistical analysis suggested by Gomez and Gomez [7] and results were compared.

Results and Discussion

Yield parameters

Based on the analysis of field data, yield and yield parameters differed statistically among the different factors (Table 1). Application of 100% RDF recorded significantly higher tuber weight (171.5 g plant⁻¹), tuber number (6.1), tuber yield under A, B and C grades (3.08, 3.58 and 4.10 t ha⁻¹ respectively) and finally total tuber yield (14.29 t ha⁻¹) compare to application of 75% RDF. The highest values for all the yield parameters were recorded under the treatment in which 100% RDF was applied and lowest value recorded under 75% RDF. This might be due to the optimum vegetative growth with the application of higher level of RDF, which ultimately responsible for accumulation of higher photosynthates in the developing tubers and produced higher fresh weight of tubers per

plant. The results are conformity with the findings of Al-Moshileh Al-Moshileh et al. [8] and with Yadu [9] observed that the increase in RDF application from 50 to 150% brought about 176 and 119% increase in marketable tubers, respectively over the control.

In general, most of the yields attributing characters of potato were significantly augmented by compost as compared to no compost level. Application of higher level of compost at 25 t ha⁻¹ recorded significantly higher tuber weight (189.6 g plant⁻¹), tuber number (6.4), tuber yield under A, B and C grades (3.61, 4.05 and 4.69 t ha⁻¹ respectively) and total tuber yield (15.81 t ha⁻¹). Due to balanced supply of nutrients to the crops throughout the crop growth period as compost undergo decomposition during which series of nutrient transformation takes place and helps in their higher availability to the crops. Higher uptake of nutrients by the crops will result in higher yield. As all the essential elements are released by the organic manures, the released essential elements play a vital functional role in crops and thus ultimately increase the yield with balanced nutrition. These results are in conformity with the findings of Vidyavathi et al. [10].

Among green manuring levels *in-situ* green manuring with cowpea recorded significantly higher tuber weight (175.6 g plant⁻¹), tuber number (6.1), tuber yield under A, B and C grades (3.23, 3.57 and 4.22 t ha⁻¹ respectively) and total tuber yield (14.64 t ha⁻¹) compare to *in-situ* green manuring with sunhemp. Significant decrease in the yield in case of sunhemp green manuring was might be due to poor biomass yield (average of 13.7 t ha⁻¹) compare to cowpea (average of 22.5 t ha⁻¹), as a result of this nutrient release and availability was more in case of cowpea which attributed to better yield and yield components than sunhemp. Same results also reported by Patel et al. [11].

The interaction effect between fertilizer levels, compost levels and *in-situ* green manuring found to be non-significant except in case of number of tubers plant⁻¹, A and B grade tuber yield. In general combined effect of fertilizer, compost and green manures enhanced the tuber yield, because of once incorporated, the compost and green manures provides a

pool of fresh organic matter and there are numerous examples showing that application of compost and green manures increased soil organic matter in comparison to treatments where inorganic fertilizers alone are applied. This organic matter provides food to soil microorganisms, encouraging an increase in numbers and activity which inturn results into better physical and chemical condition of the soil, ultimately results into loose and friable soil for the tuber development and enhanced the yield. These results are in line with the earlier findings [12–15].

Nutrient uptake

The study showed that application of 100% RDF performed better nutrient uptake than 75% RDF (Table 2). 100% RDF recorded significantly highest nutrient uptake by tubers (72.9, 16.6 and 86.3 kg N, P₂O₅ and K₂O ha⁻¹ respectively) haulms (3.6, 0.8 and 8.0 kg N, P₂O₅ and K₂O ha⁻¹ respectively) and total uptake (61.1, 13.9 and 75.3 kg N, P₂O₅ and K₂O ha⁻¹ respectively) than 75% RDF (Fig. 1). Our results are in agreement with those of Van Delden [16] and Mondal et al. [14] who reported that nutrient uptake increased with higher fertilizer rate.

Results of investigation under compost level revealed that nutrient uptake under application of compost at 25 t ha⁻¹ recorded significantly highest nutrient uptake by tubers (93.5, 21.6 and 110.7 kg N, P₂O₅ and K₂O ha⁻¹ respectively) haulms (4.6, 1.1 and 10.1 kg N, P₂O₅ and K₂O ha⁻¹ respectively) and total uptake (98.1, 22.8 and 120.8 kg N, P₂O₅ and K₂O respectively) than no compost application. This might be due to benefits of using organic manures, which releases nutrients slowly for a long time and make available to plants for their uptake. This was in accordance with the study conducted by Vidyavathi et al. [10].

In-situ green manuring with cowpea resulted in the significantly highest nutrient uptake by tubers (74.5, 17.2 and 88.1 kg N, P₂O₅ and K₂O ha⁻¹, respectively) haulms (3.6, 0.8 and 8.0 kg N, P₂O₅ and K₂O ha⁻¹ respectively) and total uptake (78.1, 18.1 and 96.2 kg N, P₂O₅ and K₂O ha⁻¹ respectively) than *in-situ* green manuring with sunhemp. Cowpea added higher biomass than sunhemp and it attribute to the mineraliza-

tion of N in soil due to high enzyme activities in the compost will increase the transformation of nutrients to available form. Role of FYM, vermicompost and green leaf manures in releasing N and improving N availability in soil was reported by Govindan and Thirumurugan [17] and Singh et al. [18].

The interaction effect between fertilizer levels, compost levels and *in-situ* green manuring found to be non-significant. The response of crops to integrated nutrient management is due to higher availability of these nutrients in soil reservoir besides the additional quantity of nutrients supplied by FYM and inorganic fertilizers. This was ascribed to continuous supply of N, P and K throughout the crop growth periods as the nutrients from inorganic sources were available to the crop in the early stages and in the later stages of the crop growth, the slow and continuous release of nutrients from the organic source made available. Pagaria et al. [19] reported that, uptake of N, P and K was increased with full dose of NPK + 10 t FYM compared to control.

Conclusion

Potato responds significantly to fertilizer, compost and green manure levels both in case of yield and nutrient uptake. Our results indicated that tuber yield of potato and its components significantly increased as fertilizer levels increased. Increase in the yield of potato in case of application of compost at 25 t ha⁻¹ was 40% compare to no compost application. *In-situ* green manuring with cowpea recorded 13.4% of more yield compare to *in-situ* green manuring with sunhemp. Besides this, cowpea added 64.2% more biomass than sunhemp. Even there is a significant difference between 75% and 100% RDF and 12.5 and 25 t ha⁻¹ of compost, we can recommend 75% RDF along with 12.5 t ha⁻¹ compost, because the reduction in the yield was to the tune of only 7.7 and 11.1% respectively compare to 100% RDF and 25 t ha⁻¹ compost respectively. While in the interaction effect of combined application of 75% RDF along with 12.5 t ha⁻¹ compost and *in-situ* green manuring with cowpea recorded only 4.1% decrease in the yield compare to combined application of 100% RDF along with 25 t ha⁻¹ compost and *in-situ* green manuring with cowpea. With this we can conclude that, application of

75% RDF along with 12.5 t ha⁻¹ compost and *in-situ* green manuring with cowpea can reduce the use of fertilizer by 25% and compost by 50% with less reduction in the yield, besides sustaining the soil fertility status.

References

1. Christopher MT (2014) Effect of green manure and intercropping on potato production in the western highlands of Cameroon. *Int J Scien and Technol Res* 3 : 204—208.
2. Millburn P, Richards JE, Gartley C, Pollock T, O'Neill H, Bailey H (1990) Nitrate leaching from systematically tilled potato fields in New Brunswick. *Canada J Environ Quality* 19 : 448—454.
3. Belanger G, Walsh JR, Richards JE, Milburn PH, Ziadi N (2001) Critical nitrogen curve and nitrogen nutrition index for potato in Eastern Canada. *Am J Potato Res* 78 : 355—364.
4. Finckh MR, Schulte-Gedermann E, Bruns C (2006) Challenges to organic potato farming : Disease and nutrient management. *Potato Res* 49 : 27—42.
5. Lynch DH, Sharifi M, Hammermeister A, Burton D (2012) Nitrogen management in organic potato production. In: *Sustainable potato production: Global case studies*. New York (NY) : Springer science + Business media, pp 209—231.
6. MC Guire AM, Bryant DC, Denison RF (1998) Wheat yields, nitrogen uptake, and soil moisture following winter legume cover crop vs fallow. *Agron J* 90 : 404—410.
7. Gomez KA, Gomez AA (1984) In: *Statistical procedures for agricultural research*. Second edn. John Wiley and Sons, New York, pp 68.
8. Al-Moshileh AM, Errebhi MA, Motawei MI (2005) Effect of various potassium and nitrogen rates and splitting methods on potato under sandy soil and arid environmental conditions. *Emir J Agric Sci* 17 : 01—09.
9. Yadu D (2011) Effect of varying levels of NPK fertilizers and size of seed tubers on growth and yield of potato (*Solanum tuberosum* L.) in Alfisol. MSc (Ag). IGKV, Raipur.
10. Vidyavathi, Dasog GS, Babalad HB, Heb-sur NS, Gali SK, Patil SG, Alagawadi AR (2011) Influence of nutrient management practices on crop response and economics in different cropping systems in a vertisol. *Karnataka J Agric Sci* 24 : 455—460.
11. Patel CK, Chaudhari PP, Patel RN, Patel NH (2010) Integrated nutrients management in potato based cropping system in North Gujarat. *Potato J* 37 : 68—70.
12. Sharma Ashwini Kumar, Singh Sarjeet (2000) Effect of farm yard manure, green manure and fertilizer levels on seed potato production in north-western hills.

- Potato J 32 : 133—144.
13. Krishnamurthy N, Abdul Khalak GM, Sujith HK, Basavaraj, Prasanna KPR, Shivaraj B (2002) Integrated nutrient supply and management for potato production in Alfisols. *Potato-Global Res Dev* 2 : 852—856.
 14. Mondal SS, Acharya Debabrata, Ghosh Arup, Bug A (2005) Integrated nutrient management on the growth, productivity and quality of potato in indogangtic plains of West Bengal. *Potato J* 32 : 75—78.
 15. Stefano Canali, Corrado Ciaccia, Daniele Antichi, Paolo Barberi, Francesco Montemurro, Fabio Tittarelli (2010) Interactions between green manure and amendment type and rate: Effects on organic potato and soil mineral N dynamic. *J Food Agri and Environ* 8 : 537—543.
 16. Van Delden A (2001) Yield and growth components of potato and wheat under organic nitrogen management. *Agron J* 93 : 1370—1385.
 17. Govindan K, Thirumurugan V (2002) Organic manure for sustaining productivity in soybean. *Finan Agri* 34 : 23—26.
 18. Singh AB, Saha JK, Ghosh PK (2008) Effect of nutrient management practices on soybean (*Glycine max*)-chickpea (*Cicer arietinum*) cropping systems for improving seed yield, quality and soil biological health under rainfed condition. *Ind J Agric Sci* 78 : 485—489.
 19. Pagaria TM, Ravankar HN, Khonde HW, Gawande RP, Labaria GS (1995) Effect of FYM with and without fertilizer on the yield and chemical composition of cotton under rainfed condition. *PKV Res J* 19 : 87—88.