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Effect of nutrients application on maize: Potato cropping sequence

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Abstract
A field experiment was conducted during 2017-18 and 2018-19 at ICAR- CPRI-RS, Gwalior M.P. during *kharif and rabi* to judge the effect of nutrients application on maize – potato cropping sequence. The experiment consisted of 8 treatments with four replications. The results revealed that application of residue based compost + Biofertilizers (*Azotobactor* and PSB) + VC @ 7.5 t/ha gave higher fresh root weight/plant (16.50 and 16.00 g/plant during 2017-18 and 2018-19, respectively) over remaining treatments at 30 DAS. However, application of 100% RDF NPK + FYM @ 25 t/ha gave higher fresh root weight at 60 DAS and maturity stage i.e. 48.25 and 41.75 g/plant, respectively during 2017. Application of 75% RDF NPK + 25% N through FYM and 75% RDF NPK + FYM @ 25 t/ha gave higher fresh root weight/plant at 60 DAS and maturity stage, respectively during 2018-19. Application of 100% RDF NPK + FYM @ 25 t/ha gave higher value of fresh plant weight at 30 DAS (174.50 and 178.75 g/plant), 60 DAS (472.75 and 460.25 g/plant) and maturity stage (539.25 and 541.50 g/plant) during 2017-18 and 2018-19, respectively. Application of residue based compost + Biofertilizers (*Azotobactor* and PSB) + VC @ 7.5 t/ha and residue based compost gave higher root: shoot ratio i.e. 0.068 and 0.69 during 2017-18 and 2018-19, respectively at 30 DAS. Residue based compost + Biofertilizers (*Azotobactor* and PSB) + VC @ 7.5 t/ha gave higher root: shoot ratio (0.073) during 2018-19 as compare to other treatments at maturity stage. Application of 75% RDF NPK + 25% N through FYM gave significantly higher use efficiencies *viz.* ANE, ENUE during both the years over 100% RDF NPK. Whereas, application of 100% RDF NPK gave higher PNE during 2018-19 compare to other treatments. Application of 100% RDF NPK + FYM @ 25 t/ha recorded higher cob (11.21 and 11.07 kg/14.4 m^2, stover (7.82 and 8.03 kg/14.4 m^2), grain (7.61 and 7.91 kg/14.4 m^2) and biological yield (14.70 and 15.80 kg/14.4 m^2) of maize during 2017-18 and 2018-19, respectively compare to other treatments. Whereas, 100% RDF NPK recorded higher stover weight *viz.*7.82 and 8.03 kg/14.4 m^2 during 2017-18 and 2018-19, respectively compare to other. Whereas, application of 100% RDF NPK + FYM @ 25 t/ha gave higher haulm (18.48 and 24.66 kg/14.4 m^2), tuber yield (46.47 and 51.24 kg/14.4 m^2), biological yield (64.95 and 75.90 kg/14.4 m^2) of potato and MEY of potato (19.57 and 18.08kg/14.4 m^2) as well as system (27.38 and 26.18 kg/14.4 m^2) during both the years. Maize fresh plant and root/plant weight was highly positive correlated with maize grain during both the years at all the stages of crop growth except at 30 DAS for root fresh weight/plant during both the years.

Keywords: Growth, yield, root: shoot ratio, nitrogen use efficiency, maize and potato

Introduction
Maize (*Zea mays* L) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. In India, maize is the third most important food crops after rice and wheat. Maize (*Zea mays* L.) is one of the main source of cereals for food, feed, forage and processed industrial products. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc.

In India, it is grown on an area of 9.86 million hectares with the annual production of 26.26 million tonnes and the productivity is 2664 kg/ha (Anonymous, 2018). Currently, Madhya Pradesh contributes about 13.02 per cent in area and 12.06 per cent in production of maize in the country. During 2016-17, area under the crop in the state was 1.28 million hectares with the annual production of 3.17 million tonnes. In India during 2016-17, highest productivity of maize was in Andhra Pradesh (6546 kg/ha) however, Madhya Pradesh was at 9th position with 1790 kg/ha [1].

Nitrogen (N) is essential for plant life and plays a key role in food production. Nitrogen is the most important crop-yield limiting factor in the world, together with water [18]. It is needed relatively in large quantities for the production of amino acids (protein), nucleic acids and chlorophyll in plants. That is why farmers use to apply N fertilizers to crop liberally at a higher rate. However, too much N leads to pollution, which is harmful for the functioning of our ecosystems and our health. Therefore, higher N use efficiency is main concern for achieving sustainable environment.

Amongst nitrogen limiting factors, the leaching is one of the major problems. Applied N to crop, dissolve in irrigation water and leaches down from the top soil surface to the downward portion. This process causes N deficiency which can easily be defined as "limited availability to plant means its limited use efficiency''. In a clear sense, lower availability of nitrogen reduces growth and development of plant. Organic manures such as farm yard manures (FYM), compost, green manure (GM), poultry and other manures improves soil fertility as well as soil texture, and encourages microbial activity ultimately conditionalize nitrogen efficacy by supporting of utilization of N and reducing leaching [12]. Considering the above fact an experiment was conducted in maize to judge the "effect of nutrients application on maize – potato cropping sequence".

Materials and Methods

The present experiment entitled "Effect of nutrients application on maize – potato cropping sequence" was carried out during two consecutive *kharif* and *rabi* seasons of 2017-18 and 2018-19 at research farm, ICAR-Central Potato Research Institute-RS, Gwalior. The experimental soil was silty-clay-loam in texture, with pH 6.84, EC 0.10 dS/m, Organic carbon 0.45% with available N (166.33 kg/ha), P (14.15 kg/ha) and K (380.56 kg/ha). The study involved eight treatment *viz*. T_1:Control, T_2:100% RDF NPK, T_3: Residue based compost + biofertilizer (*Azotobactor* and PSB), T_4:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + FYM @ 25 t/ha, T_5:Residue based compost + Biofertilizers (*Azotobactor* and PSB)+ VC @ 7.5 t/ha, T_6:100% RDF NPK + FYM @ 25 t/ha, T_7:75% RDF NPK + FYM @ 25 t/ha and T_8:75% RDF NPK + 25% N through FYM in R.B.D. design with four replications. The recommended dose of N, P_2O_5 and K_2O were 120, 60 and 40 kg/ha and 180, 80 and 120 kg/ha for the maize and potato, respectively. Nitrogen, phosphorus and potassium were applied in the form of urea, dia-ammonium phosphate (DAP) and muriate of potash (MOP), respectively. Maize and potato seeds were sown and planted at spacing 60 cm x 20 cm during *kharif* and *rabi*, respectively. The gross area of the plot was 4.8 m x 4.4 m and net area; 3.6 m x 4.0 m. Hybrid variety 'MRM-3777 and "Kufri Jyoti" were used for experimentation in maize and potato respectively. Cultural practices were followed as per standard recommendation to maize and potato.

Five maize plants were randomly sampled from the inner rows of the each plot leaving the border rows. The sampled plants were carefully dunged up, the roots thoroughly washed under running water, put in labeled envelop bags and taken to the laboratory where the growth parameters were recorded at 30, 60 DAS and maturity stage. Different N use efficiencies were determined by different formulae of N use efficiencies as suggested by Moll *et al.* [18], Weih *et al.* [23] and Dobermann [6]. Different yield parameter *viz.* cob, stover, grain and biological yield of maize and haulm, tuber and biological of potato were recorded from net plot area (14.4 m^2) and expressed in kg. Equivalent yield of maize - potato cropping sequence was calculated in terms of maize equivalent yield (MEY) by using following formula:

$$\text{MEY of potato} = \frac{\text{Potato yield}}{\text{Maize price}} \times \text{Potato price}$$

$$\text{System equivalent yield} = \frac{\text{Maize yield}}{\text{Maize price}} \times \text{Maize Price} + \text{MEY of potato}$$

During 2017-18 and 2018-19, ` 14.25 and ` 17.00/kg were the MSP price of maize, respectively whereas, ` 6.00/kg was price of potato during both the years.

Data were analyzed as per standard procedure with 5% probability level as suggested by Gomez and Gomez [7].

Results and Discussion

Fresh root weight/plant

Different nutrients treatment showed significantly impact on root fresh weight/plant at all stages of crop growth (Table 1). The fresh root weight per plant was augmented steadily in all the treatments with the advancement of plant growth up to 60 DAS and thereafter, decrease in the root fresh weight from 60 DAS to maturity stage. Application of residue based compost + Biofertilizers (*Azotobactor* and PSB) + VC @ 7.5 t/ha gave significantly higher fresh root weight/plant (16.50 and 16.00 g/plant during 2017-18 and 2018-19, respectively) over remaining treatments at 30 DAS except T_3 and T_4 in 2018-19 only. It could be possible due to higher availability of phosphorus at initial stages of root development because of PSB inoculation on seed that stimulated more root development therefore more fresh weight of root. However, application of 100% RDF NPK + FYM @ 25 t/ha gave higher fresh root weight at 60 DAS and maturity stage i.e. 48.25 and 41.75 g/plant, respectively during 2017-18 as compare to other treatment. This treatment was on par with T_8 at 60 DAS and T_7 at maturity. This may be due to higher availability of phosphorus during entire growth period because of combined application of fertilizer and FYM upto maturity. Because phosphorus is relatively, immobile nutrient in soil and diffusion is the major process controlling its movement. Hence, indirectly soil moisture regulates soil phosphorus mobility (Marschner, 1995). Addition of organic manure increased soil moisture contents [4], hence, improved P availability in soil ultimately resulted higher root fresh weight/plant. This result supported by Aziz *et al.* [2].

Table 1: Effect of nutrients application on fresh root weight of maize under maize – potato cropping sequence

Treatments	Fresh root weight/plant (g)					
	30 DAS		60 DAS		Maturity	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1:Control	9.00	9.75	29.25	30.50	24.00	22.50
T_2:100% RDF NPK	9.50	10.00	45.75	43.75	34.25	31.25
T_3:Residue based compost + Biofertilizers (*Azotobactor* and PSB)	13.25	13.75	38.50	39.75	28.50	26.00
T_4: Residue based compost + Biofertilizers (*Azotobactor* and PSB) + FYM @ 25 t/ha	15.50	14.75	40.75	42.75	33.75	31.25
T_5:Residue based compost + Biofertilizers (*Azotobactor* and PSB)+ VC @ 7.5 t/ha	16.50	16.00	43.50	41.50	29.00	31.50
T_6:100% RDF NPK + FYM @ 25 t/ha	12.25	13.00	48.25	42.00	41.75	38.25
T_7:75% RDF NPK + FYM @ 25 t/ha	10.50	11.00	41.25	42.50	37.75	38.75
T_8:75% RDF NPK + 25% N through FYM	10.00	10.75	43.00	44.75	36.00	36.25
S.E.(m)±	0.91	0.77	1.67	2.27	1.47	1.25
C.D. (at 5%)	2.67	2.27	4.93	6.67	4.33	3.67

Fresh plant weight

Overall, maize fresh weight increased with the advancement in crop age and was reached maximum at maturity stage (Table 2 and Fig 1 and 2). The rate of increase in plant fresh weight was more during 30 to 60 DAS as compared to 0 to 30 DAS and 60 DAS to maturity stage. The initial slow growth was primarily due to smaller assimilating surface area leading to lesser amount of photosynthesis. Adequate and balanced fertilization promoted the photosynthetic activity, plant growth and which ultimately produced higher fresh plant weight at later stages. The effect of various treatments with respect to plant fresh weight was found significant at all the stages of crop growth during both the years. Application of 100% RDF NPK + FYM @ 25 t/ha gave highest value of this parameter at 30 DAS (174.50 and 178.75 g/plant), 60 DAS (472.75 and 460.25 g/plant) and maturity stage (539.25 and 541.50 g/plant)during 2017-18 and 2018-19, respectively as compare to other treatments. It may be due to supply of efficient and balanced amount of nutrients at different stages of plant growth. These results confounded by Hashim [8] and Manea [14].

Table 2: Effect of nutrients application on fresh plant weight of maize under maize – potato cropping sequence

Treatments	Fresh weight (g)/plant					
	30 DAS		60 DAS		Maturity	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1:Control	108.63	110.25	268.75	278.50	322.75	316.50
T_2:100% RDF NPK	166.25	171.00	423.75	419.25	500.25	485.75
T_3:Residue based compost + Biofertilizers (*Azotobactor* and PSB)	127.50	129.25	350.75	350.75	395.25	407.25
T_4:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + FYM @ 25 t/ha	152.00	153.50	393.75	398.25	438.50	459.00
T_5:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + VC @ 7.5 t/ha	161.00	167.50	388.75	387.75	441.50	450.50
T_6:100% RDF NPK + FYM @ 25 t/ha	174.50	178.75	472.75	460.25	539.25	541.50
T_7:75% RDF NPK + FYM @ 25 t/ha	167.50	173.50	441.25	434.00	516.00	502.75
T_8:75% RDF NPK + 25% N through FYM	168.75	170.75	437.50	440.75	493.75	508.75
S.E.(m)±	7.29	6.69	16.27	14.42	10.98	13.68
C.D. (at 5%)	21.43	19.68	47.85	42.43	32.30	40.23

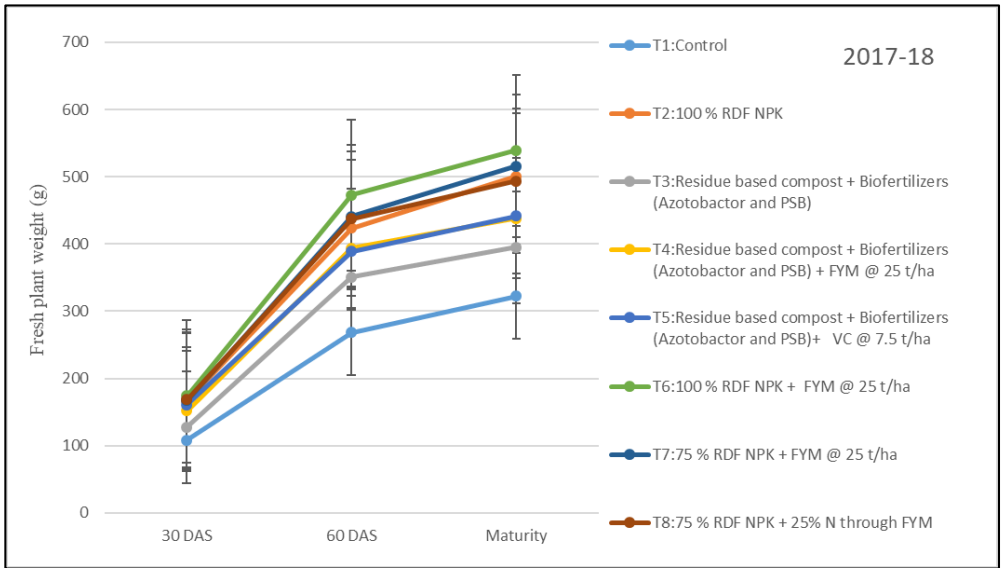

Fig 1: Fresh plant weight of maize as influenced by different nutrients application treatments under maize – potato cropping sequence during 2017-18

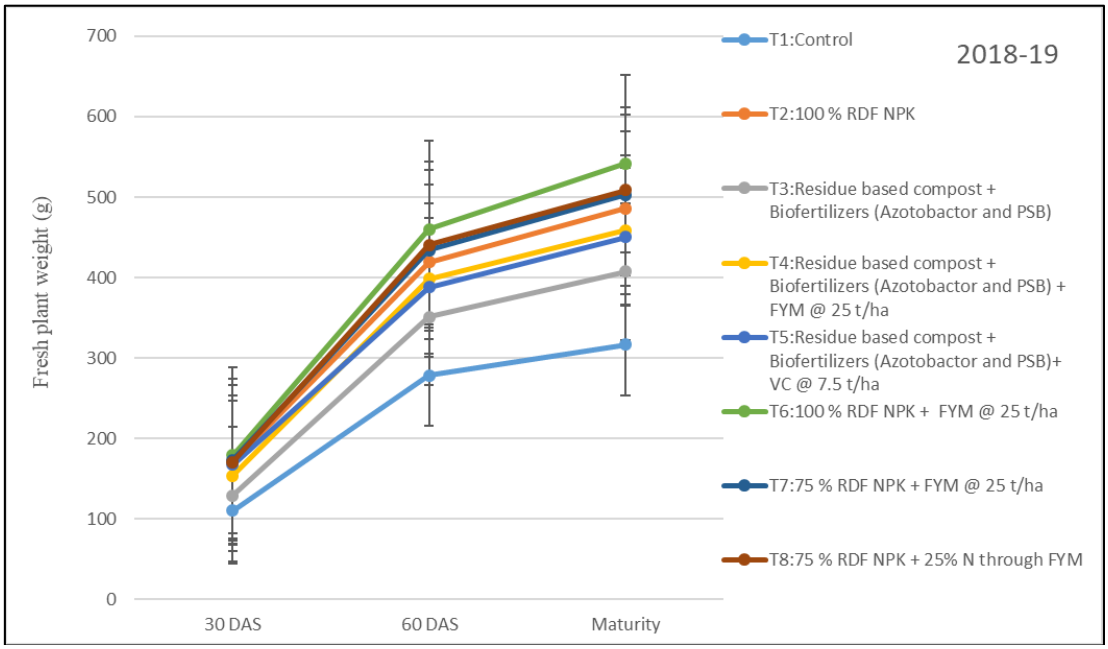

Fig 2: Fresh plant weight of maize as influenced by different nutrients application treatments under maize – potato cropping sequence during 2018-19

Root: shoot ratio

Root: shoot ratio is an important physiological parameter, which gave clear response about root growth of plant in respect to shoot growth. The different nutrients application gave significant impact upon this parameter at all the stages of crop growth except at 60 DAS during both the years and maturity stage during 2017-18 only. Application of residue based compost + Biofertilizers (*Azotobactor* and PSB)+ VC @ 7.5 t/ha and residue based composting gave higher root : shoot ratio *i.e.* 0.068 and 0.069 during 2017-18 and 2018-19, respectively at 30 DAS. These treatments were at par to each other and significantly superior compare to remaining treatments except residue based compost + Biofertilizers (*Azotobactor* and PSB) + FYM @ 25 t/ha. This may be due to higher root biomass comparison to shoot biomass owing to higher availability of phosphorus at initial stages of root development because of PSB inoculation on seed and positive effects of FYM and VC on root development resulting in more fresh weight. residue based compost + Biofertilizers (*Azotobactor* and PSB)+ VC @ 7.5 t/ha gave higher root : shoot ratio (0.073) during 2018-19 as compare to other treatments at maturity stage. This treatment was at par with control, 75% RDF NPK + FYM @ 25 t/ha and significantly superior as compare to remaining treatments. Higher root growth might be possible due to higher root biomass in comparison to shoot biomass. These results are in line with the findings of Islam *et al.* [9].

Table 3: Effect of nutrients application on root : shoot ratio of maize under maize – potato cropping sequence

Treatments	Root : shoot ratio					
	30 DAS		60 DAS		Maturity	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1:Control	0.047	0.051	0.075	0.075	0.073	0.068
T_2:100% RDF NPK	0.037	0.038	0.066	0.066	0.059	0.055
T_3:Residue based compost + Biofertilizers (*Azotobactor* and PSB)	0.067	0.069	0.069	0.072	0.058	0.057
T_4:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + FYM @ 25 t/ha	0.067	0.063	0.061	0.061	0.059	0.056
T_5:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + VC @ 7.5 t/ha	0.068	0.063	0.072	0.066	0.065	0.073
T_6:100% RDF NPK + FYM @ 25 t/ha	0.047	0.049	0.069	0.055	0.065	0.058
T_7:75% RDF NPK + FYM @ 25 t/ha	0.039	0.041	0.059	0.065	0.064	0.065
T_8:75% RDF NPK + 25% N through FYM	0.039	0.042	0.066	0.066	0.056	0.054
S.E.(m)±	0.004	0.004	0.006	0.007	0.005	0.004
C.D. (at 5%)	0.013	0.013	NS	NS	NS	0.012

Nitrogen use efficiency

Nitrogen use efficiency is the recovery of the applied fertilizer N by the harvested crop. Nutrients application gave significant effect on different type of nitrogen use efficiency (Table 3 and 4). Application of 75% RDF NPK + 25% N through FYM gave significantly higher N use efficiencies *viz.* ANE (29.90 and 35.32 kg gain/kg N applied during 2017-18 and 2018-19, respectively), ENUE (1.352 and 1.405 kg grain/` invested in N during 2017-18 and 2018-19, respectively), NRR (0.945 and 0.972 kg grain/kg N applied during 2017-18 and 2018-19, respectively) over 100% RDF NPK treatment. Application of 75% RDF NPK + 25% N through FYM gave higher value of APNE (41.34 kg grain/kg N uptake) and over 100% RDF NPK. Application of 100% RDF NPK gave higher PNE (75.11 kg biological yield/kg N uptake) during 2018-19 compare to other treatments of fertilizer application. There was non-significant effect in 2017-18 due to different nutrients application.

Table 4: Effect of nutrients application on agronomical efficiency, physiological efficiency and agro-physiological efficiency of N in maize under maize – potato cropping sequence at harvest

Treatments	Agronomic N efficiency (ANE)		Physiological N efficiency (PNE)		Agro-physiological N efficiency (APNE)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1:Control	0.00	0.00	0.00	0.00	0.00	0.00
T_2:100% RDF NPK	0.09	25.30	68.23	75.11	35.91	39.93
T_3:Residue based compost + Biofertilizers (*Azotobactor* and PSB)	-	-	-	-	-	-
T_4:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + FYM @ 25 t/ha	-	-	-	-	-	-
T_5:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + VC @ 7.5 t/ha	-	-	-	-	-	-
T_6:100% RDF NPK + FYM @ 25 t/ha	24.65	29.28	63.11	66.67	39.41	38.81
T_7:75% RDF NPK + FYM @ 25 t/ha	28.79	34.58	59.84	63.19	40.34	39.87
T_8:75% RDF NPK + 25% N through FYM	29.30	35.32	58.14	67.50	41.34	40.98
S.E.(m)±	1.79	1.93	4.24	4.03	1.98	2.34
C.D. (at 5%)	5.26	5.67	NS	11.84	5.84	NS

ANE: kg economical yield/ kg N applied **PNE:** kg biological yield/kg N uptake **APNE:** kg economical yield/kg N uptake

Application of 100% RDF NPK + FYM @ 25 t/ha gave higher value of different N use efficiency viz. ANE, ENUE, NRR over 100% RDF NPK. This result showed that application of manure along with fertilizer increased N use efficiency over un manured fertilizer alone. This is may be due to higher loss of applied nitrogen by denitrification and ammonia volatilization process. Among combined application of fertilizer and manure, application of 75% RDF gave higher N use efficiency along with either applied N basis or at the rate of 25 t/ha. This may be due to higher synergistic effect of manure in binding nitrogen and prolonging availability of applied fertilizers. Whereas, both treatment of 75% RDF gave significantly higher economical use efficiency over both 100% RDF NPK treatment owing to higher cost of fertilizer. Application of 100% RDF NPK gave higher value of N physiological efficiency as compare to other fertilizer application in 2018-19. This is may be due to less uptake of N for producing per kg of biological yield. The findings on N use efficiency also supported by Tomar *et al.* [22] and Hashim [8].

Table 5: Effect of nutrients application on utilization efficiency, economic use efficiency and removal ratio of N in maize under maize – potato cropping sequence at harvest

Treatments	Utilization N efficiency (UNE)		Economic N use efficiency (ENUE)		N removal ratio (NRR)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1:Control	0.00	0.00	0.000	0.000	0.000	0.000
T_2:100% RDF NPK	3823.25	4731.02	0.968	1.025	0.657	0.691
T_3:Residue based compost + Biofertilizers (*Azotobactor* and PSB)	-	-	-	-	-	-
T_4:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + FYM @ 25 t/ha	-	-	-	-	-	-
T_5:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + VC @ 7.5 t/ha	-	-	-	-	-	-
T_6:100% RDF NPK + FYM @ 25 t/ha	3859.79	5048.67	1.080	1.122	0.777	0.791
T_7:75% RDF NPK + FYM @ 25 t/ha	4245.64	5614.56	1.340	1.387	0.907	0.973
T_8:75% RDF NPK + 25% N through FYM	4148.10	5726.08	1.352	1.405	0.945	0.972
S.E.(m)±	264.164	378.786	0.035	0.039	0.046	0.032
C.D. (at 5%)	NS	NS	0.104	0.113	0.134	0.094

UNE: kg biological yield/kg applied N **ENUE: kg grai**n/` invested on N
NRR: kg economic yield/kg applied N

Maize yield parameter

Each plant passes through the vegetative as well as reproductive phases of growth to complete its life cycle. Yield can be considered to be the final expression of the physiological and metabolic activities of plants and is governed by various factors. Maize cob, stover, grain and biological yield kg per plot (14.4 m^2) were significantly affected due to different treatments of nutrient application during both the years (Table 6). Application of 100% RDF NPK + FYM @ 25 t/ha recorded higher cob (11.21 and 11.07 kg/plot), grain (7.61 and 7.91 kg/plot) and biological yield (14.70 and 15.80 kg/plot) during 2017-18 and 2018-19, respectively compare to other treatments including control. This may be due to combined effect of FYM and fertilizer on balanced nutrients and beneficial effect of FYM helped in increasing the availability of various macro and micronutrients in soil [8]. FYM supplies nitrogen, phosphorus and potassium in available forms to the plants in right proportion and uniformly for longer period through biological enzymic reactions along with micronutrients that resulted into higher yields. Whereas, 100% RDF NPK recorded higher stover weight *viz.*7.82 and 8.03 kg/plot during 2017-18 and 2018-19, respectively compare to other treatment. Despite higher stover weight, 100% RDF NPK treatment was unable to produce more economic yield (grain). This might be possible due to weak translocation of photosynthates from source (leaves) to sink (grain) owing to unbalanced nutrient availability especially K. Potassium have direct role in translocation of photosynthates from source to sink [5] therefore accumulated dry matter partitioning was not proper

under this treatment resulting higher stover weight. The result was supported by Kumar *et al.* [11], Mahesh *et al.* [13], Pavithra *et al.* [19], Prajapati *et al.* [20] and Tomar *et al.* [22].

Potato yield parameter

Potato haulm, tuber and biological yield kg per plot were significantly affected due to different treatments of nutrient application during both the years (Table 7).

Application of 100% RDF NPK + FYM @ 25 t/ha recorded maximum haulm yield *viz.* 18.48 and 24.66 kg/net plot during 2017-18 and 2018-19, respectively compare to other treatments. It was 153.85 and 362.66% higher compare to control treatment during 2017-18 and 2018-19, respectively. This treatment was significantly superior compare to remaining during 2017-18 and at par with T_7treatment during 2018-19. The maximum tuber yield per net plot *viz.* 46.47 and 51.24 kg/plot during 2017-18 and 2018-19, respectively under 100% RDF NPK + FYM @ 25 t/ha treatment compare to other treatments. It was 100.47, 125.82 and 112.95% higher compare to control treatment. While, it was at par with T_8 treatment in 2017-18 and with T_7, T_2 treatment in 2018-19. 100% RDF NPK+ FYM @ 25 t/ha recorded maximum biological yield *viz.* 64.95 and 75.90 during 2017-18 and 2018-19, respectively compare to other treatments. This treatment was at par with T_8 and T_7 treatment, in 2017-18 and 2018-19, respectively and significantly superior compare to other treatments at pooled basis. This treatment gave 113.2 and 170.88% higher biological yield compare to control treatment. This may be due to combined effect of FYM and fertilizer on balanced nutrients and beneficial effect of FYM help in increasing the availability of various macro and micronutrients in soil [8]. FYM supplies nitrogen, phosphorus and potassium in available forms to the plants in right proportion and uniformly for longer period through biological decomposition along with micronutrients that resulted in higher yields. This result supported by Ahmed *et al.* [2], Balemi [3], Koireng *et al.* [10] and Mohammed *et al.* [16].

Equivalent yield

Different sources of nutrient application gave significant effect on equivalent yield parameter *viz.* Maize equivalent of potato and system (Table 4.9). Application of 100% RDF NPK + FYM @ 25 t/ha gave significantly higher equivalent yield of potato (19.57 and 18.08 kg/14.4 m^2) as compare to other treatments except T_8 treatment during 2017-18 and T_7, T_2 treatment during 2018-19 from which it was at par. This may be due to higher economical yield of potato under this treatment. In 2017-18 MEY of potato was more as compare to 2018-19. This may be due to higher MSP of maize in the course of 2018-19. Application of 100% RDF NPK + FYM @ 25 t/ha also gave significantly higher system equivalent yield (27.38 and 26.18 m^2, respectively) as compare to other treatments except T_8 during2017-18 and T_7 during 2017-18 and 2018-19, respectively from which was at par. This may be due to higher economical yield of both crop under this treatment. This result also supported by Singh and Lal [21] and Hashim [8].

Table 6: Effect of nutrients application on yield parameter of maize under maize – potato cropping sequence

Treatments	Kg/plot (14.4 m^2)							
	Cob		Stover		Grain		Biological	
	2017-18	2017-18	2018-19	2018-19	2017-18	2017-18	2018-19	2018-19
T_1:Control	6.59	5.36	4.68	4.23	3.35	2.85	8.03	7.08
T_2:100% RDF NPK	10.44	10.61	7.82	8.03	6.82	7.22	14.64	15.26
T_3:Residue based compost + Biofertilizer (*Azotobactor* and PSB)	8.51	8.94	4.83	5.34	4.61	5.11	9.44	10.45
T_4:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + FYM @ 25 t/ha	10.00	9.97	6.20	6.42	5.79	6.26	11.99	12.68
T_5:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + VC @ 7.5 t/ha	10.40	10.12	5.39	5.64	5.98	6.48	11.37	12.12
T_6:100% RDF NPK + FYM @ 25 t/ha	11.21	11.07	7.09	7.89	7.61	7.91	14.70	15.80
T_7:75% RDF NPK + FYM @ 25 t/ha	10.63	10.50	6.45	7.02	7.08	7.33	13.54	14.36
T_8:75% RDF NPK + 25% N through FYM	10.78	11.07	6.26	7.07	7.15	7.43	13.41	14.50
S.E.(m)±	0.35	0.35	0.30	0.38	0.28	0.28	0.37	0.53
C.D. (at 5%)	1.03	1.03	0.88	1.13	0.83	0.82	1.08	1.56

Table 7: Effect of nutrients application on yield parameter of potato under maize – potato cropping sequence

Treatments	Fresh yield (kg/14.4 m^2)					
	Haulm		Tuber		Biological	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1:Control	7.28	5.33	23.18	22.69	30.46	28.02
T_2:100% RDF NPK	16.69	18.47	38.82	46.79	55.51	65.26
T_3: Residue based composting	7.41	6.70	26.56	25.64	33.97	32.34
T_4:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + FYM @ 25 t/ha	9.31	8.30	33.74	32.70	43.05	41.00
T_5: Residue based compost + Biofertilizers (*Azotobactor* and PSB) + VC @ 7.5 t/ha	7.61	7.00	28.23	26.05	35.84	33.05
T_6:100% RDF NPK + FYM @ 25 t/ha	18.48	24.66	46.47	51.24	64.95	75.90
T_7:75% RDF NPK + FYM @ 25 t/ha	15.39	23.58	40.50	49.56	55.89	73.14
T_8:75% RDF NPK + 25% N through FYM	16.46	18.18	46.15	45.07	62.62	63.25
S.E.(m)±	0.56	0.53	1.59	1.56	1.64	1.56
C.D. (at 5%)	1.64	1.55	4.68	4.59	4.82	4.58

Table 8: Effect of different nutrient application on MEY of potato and system under maize – potato cropping sequence

Treatments	MEY of potato kg/14.4 m^2		MEY of the system kg/14.4 m^2	
	2017-18	2018-19	2017-18	2018-19
T_1:Control	9.76	8.01	13.24	10.96
T_2:100% RDF NPK	16.35	16.51	23.39	23.93
T_3: Residue based composting	11.18	9.05	15.94	14.29
T_4:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + FYM @ 25 t/ha	14.21	11.54	20.17	17.95
T_5:Residue based compost + Biofertilizers (*Azotobactor* and PSB) + VC @ 7.5 t/ha	11.89	9.19	18.02	15.80
T_6:100% RDF NPK + FYM @ 25 t/ha	19.57	18.08	27.38	26.18
T_7:75% RDF NPK + FYM @ 25 t/ha	17.05	17.49	24.31	24.99
T_8:75% RDF NPK + 25% N through FYM	19.43	15.91	26.76	23.50
S.E.(m)±	0.69	0.70	0.76	0.64
C.D. (at 5%)	2.03	2.05	2.24	1.89

Table 9: Correlation between maize yield and different growth parameter of maize under maize – potato cropping sequence

Particular	Stage	r	R^2	Linear equation
Per plant fresh weight (g) during 2017-18	30 DAS	0.984095**	0.968444	y = 0.0614x - 3.3684
	60 DAS	0.988817**	0.977759	y = 0.0224x - 2.8465
	Maturity	0.990441**	0.980973	y = 0.0201x - 3.1019
Per plant fresh weight (g) 2018-19	30 DAS	0.975735**	0.952059	y = 0.0658x - 3.991
	60 DAS	0.991265**	0.982606	y = 0.028x - 4.7527
	Maturity	0.99099**	0.982062	y = 0.0232x - 4.3138
Root : shoot ratio during 2017-18	30 DAS	-0.43211^{NS}	0.186718	y = -45.723x + 8.3978
	60 DAS	-0.559^{NS}	0.312476	y = -152.15x + 16.262
	Maturity	-0.45705^{NS}	0.208895	y = -120.53x + 13.567
Root : shoot ratio during 2017-18	30 DAS	-0.41062^{NS}	0.16861	y = -58.017x + 9.3406
	60 DAS	-0.79848*	0.637573	y = -215.11x + 20.467
	Maturity	-0.38399^{NS}	0.147447	y = -90.604x + 11.828
Fresh root/plant (g) during 2017-18	30 DAS	-0.007141^{NS}	5.09946	y = -0.0037x + 6.0931
	60 DAS	0.905938**	0.820723	y = 0.2297x - 3.4336
	Maturity	0.927294**	0.859875	y = 0.236x - 1.7703
Fresh root/plant (g) during 2017-18	30 DAS	0.131332^{NS}	0.017248	y = 0.093x + 5.1727
	60 DAS	0.921313**	0.848818	y = 0.3406x - 7.6177
	Maturity	0.918972**	0.84451	y = 0.2648x - 2.1421

Note:** Significant at p= 0.01% level, ***** Significant at p= 0.05% level, ^{NS} Non-significant

Correlation

Correlation between maize yield and growth parameter (root and plant fresh weight) gave significant effect during 2017-18 and 2018-19 (Table 9) at all the stages of crop growth except at 30 DAS in respect to root fresh weigh. Root : shoot ratio resulted non-significant effect during both the years at all the stages of crop growth except at 60 DAS during 2017-18.

Fresh weight/plant gave 0.984095, 0.988817, 0.990441 value of 'r' during 2017-18 and 0.975735, 0.991265, 0.99099 during 2018-19 at 30, 60 DAS and maturity stages, respectively. These correlations were significant at 0.01 level of significance. y = 0.0614x - 3.3684, y = 0.0224x - 2.8465, y = 0.0201x - 3.1019 during 2017-18 and y = 0.0658x - 3.991, y = 0.028x - 4.7527, y = 0.0232x - 4.3138 during 2018-19 were the linear equation of fresh weight/plant at 30, 60 DAS and maturity stages, respectively.

Fresh root weight gave 0.820723, 0.859875 value of 'r' during 2017-18 and 0.848818, 0.84451 during 2018-19 at 60 DAS and maturity stages, respectively. These correlations were significant at 0.01 level of significance. y = 0.2297x - 3.4336, y = 0.236x - 1.7703 during 2017-18 and y = 0.3406x - 7.6177, y = 0.2648x - 2.1421 during 2018-19 were the linear equation of fresh weight/plant at 60 DAS and maturity stages, respectively.

Summary and Conclusion

- Application of 100% RDF NPK + FYM @ 25 t/ha is the better treatment as compare to other treatments for achieving higher value of growth (Fresh root and plant weight) and yield parameter of maize (cob, grain and biological), potato (haulm, tuber and biological) and MEY of potato as well as system.
- Application of 75% RDF NPK + 25% N through FYM gave higher N use efficiency in most of cases followed by 75% RDF NPK + FYM @ 25 t/ha. Therefore, application of 75% RDF NPK + 25% N through FYM followed by 75% RDF NPK + FYM @ 25 t/ha are the better options for achieving higher N use efficiency in maize crop.

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