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Effect of different sources of nutrient management on yield and economics of potato + maize intercropping system in north Bihar region

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Abstract
A field experiment was conducted during *Rabi* season of 2020-21 at Tirhut College of Agriculture Farm, Dholi (Muzaffarpur), Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar, in order to explore the possibility of improving the yield and economics of both potato and maize crops by the use of integrated nutrient management under potato + maize intercropping system. Potato was intercropped with maize (1:1), having 100 percent population of both the crops. The results obtained after statistical analysis of data revealed that the potato tuber yield (t/ha), vine yield, biomass yield, maize grain yield, stover yield, stone yield and biomass yield showed the beneficial effect from the use of integrated levels of NPK and FYM. The treatment T_{14} (125% RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}) gave higher yield and better B:C in intercropping system, it was also found to give higher yield in terms of potato equivalent yield. T_{14} was found to be at par with T_{10} (RDF of potato + 100% RDF of maize + 20 t FYM ha^{-1}), T_{12} (RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}) and T_{13} (125% RDF of potato + 125% RDF of maize + 10 t FYM ha^{-1}) in terms of both yield and economics.

Keywords: Integrated nutrient management, potato equivalent yield, biomass yield, intercropping

Introduction
Potato and maize are two major food crops in India. Potato (*Solanum tuberosum* L.) is a carbohydrate-rich, low fat food crop which is herbaceous annual in nature, which grows up to 100 cm and contributes substantially towards food and nutritional security in India. It's originated from the high Andean hills of South America. Maize (*Zea mays* L.) is one of the most important cereal crop in India agriculture as food, feed and industrial raw material and ranked third following rice and wheat. In Bihar potato is grown in 0.33 million ha with a production of 8.5 million tonnes and a productivity of 25.84 MT/ha while *Rabi* maize occupies an area of 0.46 million ha in Bihar with a production and productivity of 1.9 million tonnes and 4081 kg/ha respectively (Anon., 2021) [1]. To meet the needs of the ever increasing population there is a need to improve the land use efficiency (LUE). One such way to improve land use efficiency is through intercropping of companion crops including winter potato (*Solanum tuberosum* L.) and maize (*Zea mays* L.). *Rabi* potato being a short duration crop leaves much of the residual soil nutrients which can be utilized by maize as it is a slow growing (especially during winters) crop. *Rabi* maize also provide sufficient time and space in the field to incorporate short duration intercrops. Maize, because of similar cultural requirements (especially earthing up and furrow irrigation) fits best as intercrop in *Rabi* potato. The continuous use of chemical fertilizers has led to imbalance of nutrients in soil, which has an adverse effect on soil health and also on crop yields. While use of organic manure alone does not result in spectacular increase in crop yield due to their low nutrients content and slow availability (Kumar *et al.* 2016) [4]. Integrated use of organic sources of nutrient along with chemical fertilizer is of great importance for the maintenance of soil health and productivity of crop from per unit area of land. Integrated nutrient management helps in the maintenance of soil fertility at an optimum level which ensure to enhance crop productivity to get the maximum benefit from all possible combination of sources of nutrients – organic as well as inorganic, in an integrated manner (Shukla *et al.* 2013) [8]. Moreover farm yard manure (FYM) is available with farming community in profuse quantity. For preparation of FYM, there is no need of expensive technology and frame of structure like vermicompost manufacturing unit.

FYM can be prepared at domestic level by adopting only a few inputs, care and at most negligible expenditure with the engagement of family members only. Keeping all these facts in view, an experiment was conducted to investigate the effect of integrated nutrient management on *Rabi* potato + maize intercropping.

Materials and Methods

The field experiment was conducted during the *Rabi* seasons 2020-21 in plot number 13 at Tirhut College of Agriculture Farm, Dholi (Muzaffarpur), Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar, which is located on the southern bank of the river Burhi Gandak at an elevation of 52.2 m above mean sea level and lies at 25º98' north (N) latitude and 85º60' east (E) longitude. The experimental plot was upland and well drained with uniform topography, homogenous fertility, and uniform textural make-up. The soil of the experimental field was calcareous-alluvium in nature and slightly alkaline in reaction, due to the deposition of sediments by the Burhi Gandak River. Generally, the sediment brought by Gandak contains a higher amount of free calcium carbonate ranging from 10-45% which was spread throughout the soil layer. It has a pH of 8.21, low organic carbon (0.36%), low available nitrogen (226.78 kg/ha) and available phosphorus (P_2O_5) (21.25 kg/ha) and medium available potassium (K_2O) (142.42 kg/ha). The experiment was laid out in randomized block design (RBD) with three replications. It consisted of 14 nutrient combinations *viz s*., T_1 (RDF for sole potato), T_2 (RDF for sole maize), T_3 (control potato + maize, no fertilizer and FYM), T_4 (RDF for potato + RDF for maize), T_5 (RDF for potato + 50% RDF for maize + 10 t FYM ha^{-1}), T_6 (RDF for potato + 50% RDF for maize + 20 t FYM ha^{-1}), T_7 (RDF for potato + 75% RDF for maize + 10 t FYM ha^{-1}), T_8 (RDF for potato + 75% RDF for maize + 20 t FYM ha^{-1}), T_9 (RDF for potato + 100% RDF for maize + 10 t FYM ha^{-1}), T_{10} (RDF for potato + 100% RDF for maize + 20 t FYM ha^{-1}), T_{11} (RDF for potato + 125% RDF for maize + 10 t FYM ha^{-1}), T_{12} (RDF for potato + 125% RDF for maize + 20 t FYM ha^{-1}), T_{13} (125% RDF for potato +125% RDF for maize + 10 t FYM ha^{-1}) and T_{14} (125% RDF for potato +125% RDF for maize + 20 t FYM ha^{-1}). The variety used for potato was *Kufri Ashoka* while that of maize was Shaktiman-5. The RDF of potato and maize were 150:90:100 kg ha^{-1} (NPK) and 150:75:50 kg ha^{-1} (NPK) respectively. The spacing was maintained at 60 cm x 20 cm for both the crops. Maize was sown on the side of the ridges after 7 days after planting of potato. The population of both the crops were maintained at 100%. Potato was planted on 24th November 2020 and maize was sown on 1st December 2020. For potato half dose of N and whole amount of P_2O_5 and K_2O was applied as basal at the time of sowing. Remaining dose of N was applied after 30 days after planting. In case of maize half dose of N and entire dose of P_2O_5 and K_2O was applied at the time of sowing. Remaining dose of N was applied in two equals split ¼ at knee-high stage and rest ¼ at tasseling stage. Irrigation was provided as and when required and timely plant protection measures were taken. The other management practices were adopted as per the recommendations of the crops. During the trial meteorological parameters were suitable for normal growth of both the crops. Potato crop was harvested in the first week of March, 2021 and maize crop was harvested at full maturity during third week of May, 2021. Observations on the tuber yield and maize grain yield were assessed on the basis of the produced recorded from the net plot (3.00 m × 3.20 m). The statistical analysis was carried out as described by Gomez and Gomez (1984) [2]. The yields of crops were converted to potato equivalent yield (PEY) as suggested by Tomar and Tiwari (1990) [12] on the basis of the existing market prices of the crops as follows:

$$\text{Potato equivalent yield} = \frac{\text{Maize grain yield (q/ha) x Market price of maize (per q)}}{\text{Market price of potato (per q)}} + \text{Yield of tuber (q/ha)}$$

Gross and net returns were computed using prevailing rates of produce and agro inputs.

Benefit cost ratio (B: C) was calculated using the formula given below:

$$\text{B: C} = \frac{\text{Gross return (₹ per ha)}}{\text{Cost of cultivation(₹ per ha)}}$$

Results and Discussion

Yield of Potato

The maximum fresh tuber yield was recorded from T_{14}: 125% RDF for potato + 125% RDF for maize + 20 t FYM ha^{-1} (26.40 t ha^{-1}) (Table 1). It gave 170.5% more tuber yield than T_3: control potato + maize, no fertilizer and FYM. It was found to be at par with T_{10}: RDF for potato + 100% RDF for maize + 20 t FYM ha^{-1}, T_{12}: RDF for potato + 125% RDF for maize + 20 t FYM ha^{-1} and T_{13}: 125% RDF for potato + 125% RDF for maize + 10 t FYM ha^{-1}. This might be due to application of fertilizer in combination with organic manure (FYM), which can increase nutrient use efficiency by modifying soil physical condition in such a way that it increase total nutrients uptake because of better root penetration leading to better nutrient adsorption as well as that of moisture (Yadav *et al.*, 2013) [14]. A similar report was made by Kushwah *et al.* (2005) [6] that manure have sufficient residual effect on soil nutrients supply system. Organic manure also supply micronutrients in addition to major plant nutrients. Similar pattern was also observed in case of vine yield and biomass yield, where significantly higher values of both vine yield (12.25 t ha^{-1}) and biomass yield (38.65 t ha^{-1}) being recorded from T_{14} while being at par with T_{10}, T_{12} and T_{13}. The increase in the vine yield was mainly due to the increase in the levels of nutrients at each successive level. The application of nitrogen in particular, at higher levels was found to be beneficial and results in a higher yield of vines. The addition of organic manures has led to enhance organic carbon content, the availability of macro and micronutrients, beneficial microorganism activity, and release of nutrients during the entire crop growth period promoting in higher plant height, number of shoots plant^{-1}, leaves plant^{-1} and resulted in a greater quantity of dry matter production. These leads to overall increase in biomass yield with the application of increased level of nutrients along with organic manure. Similar findings were reported by Porwal *et al.* (2006) [7] and Verma *et al.* (2018) [13]. Tuber: vine ratio and harvest index did not differ significantly between different treatments. However relatively higher values of tuber: vine ratio (2.21) and harvest index (68.82%) were observed from T_6: RDF of potato + 50% RDF of maize + 20 t FYM ha^{-1}.

Table 1: Effect of integrated nutrient management on fresh tuber yield, vine yield, biomass yield, Tuber: vine ratio and harvest index of potato.

Treatments	Fresh yield of tuber (t ha^{-1})	Vine yield (t ha^{-1})	Biomass yield (t ha^{-1})	Tuber: vine	Harvest index (%)
T_1: RDF for sole potato	23.41	10.86	34.28	2.16	68.31
T_3: Potato + maize (control)	9.76	4.61	14.37	2.12	67.91
T_4: RDF of potato + RDF of maize	22.35	10.27	32.61	2.18	68.52
T_5: RDF of potato + 50% RDF of maize + 10 t FYM ha^{-1}	21.54	10.02	31.57	2.15	68.24
T_6: RDF of potato + 50% RDF of maize + 20 t FYM ha^{-1}	23.35	10.58	33.92	2.21	68.82
T_7: RDF of potato + 75% RDF of maize + 10 t FYM ha^{-1}	22.64	10.48	33.13	2.16	68.35
T_8: RDF of potato + 75% RDF of maize + 20 t FYM ha^{-1}	23.08	11.05	34.13	2.09	67.62
T_9: RDF of potato + 100% RDF of maize + 10 t FYM ha^{-1}	21.84	10.75	32.59	2.03	67.02
T_{10}: RDF of potato + 100% RDF of maize + 20 t FYM ha^{-1}	24.07	11.53	35.60	2.09	67.61
T_{11}: RDF of potato + 125% RDF of maize + 10 t FYM ha^{-1}	23.77	11.24	35.01	2.12	67.90
T_{12}: RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}	25.69	12.06	37.75	2.13	68.05
T_{13}: 125% RDF of potato + 125% RDF of maize + 10 t FYM ha^{-1}	24.93	11.71	36.64	2.13	68.04
T_{14}: 125% RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}	26.40	12.25	38.65	2.15	68.30
S.Em (±)	0.81	0.34	1.08	0.07	2.27
CD (*p*=0.05)	2.35	0.99	3.16	NS	NS

Maize Yield

Maize grain yield, stover yield, stone yield and biomass yield differ significantly with different treatments. Significantly higher grain yield (9.04 t ha^{-1}), stover yield (14.13t ha^{-1}), stone yield (1.78 t ha^{-1}) and biomass yield (23.17 t ha^{-1}) were observed from T_{14}: 125% RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}(table 2). The treatments T_{10}: RDF for potato + 100% RDF for maize + 20 t FYM ha^{-1}, T_{12}: RDF for potato + 125% RDF for maize + 20 t FYM ha^{-1} and T_{13}: 125% RDF for potato +125% RDF for maize + 10 t FYM ha^{-1} were found to be at par with T_{14}. The harvest index does not varied significantly between the treatments, however relatively higher harvest index was observed from T_{12} (RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}). The increase in grain yield of maize might be due to effective utilization of applied nutrients which increased the sink capacity of crop. Similar results were also found by Thavaprakash *et al.* (2005) [15]. Integration of inorganic fertilizers and organic manure sustained the crop production due to positive interaction and complementarities between them, these findings are in close conformity with the findings of Sujatha *et al.* (2008) [10] who reported that significant increase in yield components with increasing organic manure and inorganic fertilizers was due to higher nutrient availability and uptake with the higher rates of both fertilizer types which increased the availability of plant nutrients (Kundu 2007) [5]. The result clearly revealed that the yield parameters of maize could be increased by the interaction of organic and inorganic fertilizer.

Table 2: Effect of integrated nutrient management on grain yield, stover yield, biomass yield, stone yield and harvest index of maize.

Treatments	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biomass yield (t ha^{-1})	Stone yield (t ha^{-1})	Harvest index (%)
T_2: RDF for sole maize	8.37	12.37	20.74	1.55	37.55
T_3: Potato + maize (control)	2.67	5.47	8.14	0.38	31.34
T_4: RDF of potato + RDF of maize	8.00	12.15	20.15	1.33	37.24
T_5: RDF of potato + 50% RDF of maize + 10 t FYM ha^{-1}	6.90	11.01	17.91	1.03	36.43
T_6: RDF of potato + 50% RDF of maize + 20 t FYM ha^{-1}	7.74	11.62	19.36	1.35	37.37
T_7: RDF of potato + 75% RDF of maize + 10 t FYM ha^{-1}	6.94	11.21	18.15	1.12	36.01
T_8: RDF of potato + 75% RDF of maize + 20 t FYM ha^{-1}	8.03	12.25	20.28	1.49	36.89
T_9: RDF of potato + 100% RDF of maize + 10 t FYM ha^{-1}	7.71	11.89	19.60	1.30	36.89
T_{10}: RDF of potato + 100% RDF of maize + 20 t FYM ha^{-1}	8.66	12.94	21.60	1.70	37.17
T_{11}: RDF of potato + 125% RDF of maize + 10 t FYM ha^{-1}	8.10	12.43	20.53	1.61	36.59
T_{12}: RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}	8.97	13.12	22.09	1.78	37.58
T_{13}: 125% RDF of potato + 125% RDF of maize + 10 t FYM ha^{-1}	8.81	13.22	22.03	1.73	37.08
T_{14}: 125% RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}	9.04	14.13	23.17	1.86	36.12
S.Em (±)	0.29	0.44	0.85	0.06	1.69
CD (*p*=0.05)	0.86	1.28	2.47	0.17	NS

Potato Equivalent Yield

The potato equivalent yield (PEY) differed significantly due to different treatments allocation (Table 3). It was found to be significantly higher with treatment T_{14}: 125% RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1} (37.70 t ha^{-1}) which was at par with T_{10}: RDF for potato + 100% RDF for maize + 20 t FYM ha^{-1}, T_{12}: RDF for potato + 125% RDF for maize + 20 t FYM ha^{-1} and T_{13}: 125% RDF for potato +125% RDF for maize + 10 t FYM ha^{-1}. The results are in agreement with the findings of Jha *et al.* (2000) [3] and Singh *et al.* (2002) [9]. High PEY owing to potato + maize intercropping system is attributed to high gross income obtained because of combined additional yield of potato and maize. The addition of inorganic fertilizers with organic manures increased PEY due to the complementary effect of organic and inorganic sources of nutrients. This results are in accordance with findings of Thavaprakash *et al.* (2005) [15].

Economics

Table 3: Effect of integrated nutrient management on potato equivalent yield in potato + maize intercropping system.

Treatment	PEY (t ha^{-1})
T_1: RDF for sole potato	23.41
T_2: RDF for sole maize	10.46
T_3: Potato + maize (control)	13.09
T_4: RDF of potato + RDF of maize	32.34
T_5: RDF of potato + 50% RDF of maize + 10 t FYM ha^{-1}	30.16
T_6: RDF of potato + 50% RDF of maize + 20 t FYM ha^{-1}	33.03
T_7: RDF of potato + 75% RDF of maize + 10 t FYM ha^{-1}	31.32
T_8: RDF of potato + 75% RDF of maize + 20 t FYM ha^{-1}	32.72
T_9: RDF of potato + 100% RDF of maize + 10 t FYM ha^{-1}	31.88
T_{10}: RDF of potato + 100% RDF of maize + 20 t FYM ha^{-1}	35.07
T_{11}: RDF of potato + 125% RDF of maize + 10 t FYM ha^{-1}	33.89
T_{12}: RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}	36.52
T_{13}: 125% RDF of potato + 125% RDF of maize + 10 t FYM ha^{-1}	36.15
T_{14}: 125% RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}	37.70
SE (m)±	1.19
CD (p=0.05)	3.46

The economics of potato + maize intercropping system in terms of gross return, net return and B: C were significantly influenced by different treatments (Table 4). Application of 125% RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1} (T_{14}) resulted in significantly higher gross return (452395 ₹ ha^{-1}) as well as net return (270615 ₹ ha^{-1}). And it was superior over others treatments while being at par with T_{10}: RDF of potato + 100% RDF of maize + 20 t FYM ha^{-1}, T_{12}: RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1} and T_{13}: 125% RDF of potato + 125% RDF of maize + 10 t FYM ha^{-1}. The benefit cost ratio (B:C) was significantly higher in T_1: RDF for sole potato (2.70), this was due to lesser cost of cultivation incurred in sole cropping as compared to intercropping. In intercropping system T_{13}: 125% RDF of potato + 125% RDF of maize + 10 t FYM ha^{-1} (2.56) recorded higher B: C as compared to T14: 125% RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}. This was due to lesser cost of cultivation in T_{13} (169200 ₹ ha^{-1}) as compared to T_{14} (181780 ₹ ha^{-1}) and also the gross return and net return obtained in T_{13} (433744 and 264544 ₹ ha^{-1} respectively) was at par to that of T_{14} (452395 and 270615 ₹ ha^{-1} respectively). This results confirms the findings of Jha *et al.* (2000) [3] and Singh *et al.* (2002) [9] who also reported that higher monetary return and B:C were observed with increasing nutrients application in combination with organic manures under potato + maize intercropping system.

Table 4: Effect of integrated nutrient management on economics of potato + maize intercropping system.

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C
T_1: RDF for sole potato	103919	280956	177037	2.70
T_2: RDF for sole maize	49287	125525	76238	2.55
T_3: Potato + maize (control)	134659	157066	22407	1.17
T_4: RDF of potato + RDF of maize	153207	388112	234905	2.53
T_5: RDF of potato + 50% RDF of maize + 10 t FYM ha^{-1}	161324	361929	200605	2.24
T_6: RDF of potato + 50% RDF of maize + 20 t FYM ha^{-1}	173904	396305	222401	2.28
T_7: RDF of potato + 75% RDF of maize + 10 t FYM ha^{-1}	163147	375774	212627	2.30
T_8: RDF of potato + 75% RDF of maize + 20 t FYM ha^{-1}	175727	392614	216887	2.23
T_9: RDF of potato + 100% RDF of maize + 10 t FYM ha^{-1}	164971	382568	217597	2.32
T_{10}: RDF of potato + 100% RDF of maize + 20 t FYM ha^{-1}	177551	420884	243333	2.37
T_{11}: RDF of potato + 125% RDF of maize + 10 t FYM ha^{-1}	166794	406699	239905	2.44
T_{12}: RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}	179374	438551	259177	2.44
T_{13}: 125% RDF of potato + 125% RDF of maize + 10 t FYM ha^{-1}	169200	433744	264544	2.56
T_{14}: 125% RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1}	181780	452395	270615	2.49
S.Em (±)	-	12861	9659	0.12
CD (*p*=0.05)	-	37386	28077	0.34

Conclusion

Based on the results of the field experiment it can be concluded that potato + maize intercropping system is highly remunerative and the integrated application of both inorganic fertilizers and organic manures (FYM) is highly recommended as it can improve the overall productivity as well as the economics of the intercropping system. Application of 125% RDF of potato + 125% RDF of maize + 20 t FYM ha^{-1} (T_{14}) gave significantly higher yield in both potato and maize and better economics in terms of gross return and net return. But keeping in view the importance of mitigating the adverse effect of high fertilizer inputs on soil health as well as minimizing the overall cost of cultivation, we can adopt the application of RDF of potato + 100% RDF of maize + 20 t FYM ha^{-1} (T_{10}) as it was at par with T_{14} in terms of yields, gross return, net return and B: C ratio.

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