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Research Paper

Effect of sources and levels of nutrients on growth and yield behaviour of pop corn (*Zea mays*) and potato (*Solanum tuberosum*) sequence

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ABSTRACT

A field experiment was conducted during 2008–09 and 2009–10 at New Delhi, to study the effect of organic sources of nutrients on growth, yield and yield attributes of pop porn (*Zea mays* averta Sturt)-potato (*Solanum tuberosum* L.) cropping system. The experiment consisted of 24 treatment combinations with 8 treatments in pop corn [control, recommended dose of fertilizers (RDF) ($N_{120}P_{25}K_{35}$ kg/ha), farmyard manure equivalent to120 kg N/ha (FYM_{120}), leaf compost equivalent to 120 kg N/ha (LC_{120}), vermicompost equivalent to 120 kg N/ha (VC_{120}), farmyard manure equivalent to 90 kg N/ha (FYM_{90}), leaf compost equivalent to 90 kg N/ha (LC_{90}) and vermicompost equivalent to 90 kg N/ha (VC_{90})] and 3 treatments in potato crop [control, farmyard manure equivalent to 60 kg N/ha (FYM_{60}) and farmyard manure equivalent to 90 kg N/ha (FYM_{90})]. The application of RDF ($N_{120}P_{25}K_{35}$ kg/ha) recorded significantly highest plant height, leaf-area index and dry matter with higher values of yield attributes, viz. cob length and girth, cobs/ha over the control. Application of vermicompost equivalent to 120 kg N/ha was the best source and remained at par with VC_{90}, FYM_{120}, FYM_{90} and $N_{120}P_{25}K_{35}$ kg/ha for growth and yield attributes of pop corn. Similar trend in respect of grain and stover yield was also found. Due to residual fertility of FYM (equivalent to 120 kg N/ha) potato recorded the highest plant height, LAI, number of haulms and dy matter in haulms. Both FYM (equivalent to 90 kg/ha) and vermicompost (equivalent to 120 kg N/ha) exhibited the effects similar to FYM @ 120 kg N/ha. The yield and yield attributes of potato, viz. tubers/hill, fresh and dry weight of tubers, tuber yield and haulm yield also exhibited similar trend. Regarding direct effects of FYM, application of FYM equivalent to 90 kg N/ha in potato recorded the higher plant height, LAI, haulms/hill, dry matter in haulms; and yield and yield attributes compared to FYM equivalent 60 kg N/ha and control.

Key words **:** Crop production, Farmyard manure, Leaf compost, Pop corn, Potato, Vermicompost

Over the last decade, maize is the only cereal, which has registered positive growth rate in terms of production and productivity and presently it has 8.9% growth in production (DMR, 2013). It is considered as one of the potential driver for crop diversification in India and grown for various purposes in our country. Pop corn is ones of the major one and is prominently used in preparation of snacks in different parts of the world. Potato is another short-duration, contributing to world food basket just after rice, wheat and maize. It can be fitted suitably into different cropping system to increase the efficiency of time and resources (Sharma *et al*., 2006). Maize–potato cropping system has potential to become a successful cropping system is northern plains zone and central zone of India, indicating that potato inclusion in cropping systems are usually more profitable than cereal-based cropping systems (Pandey *et al.,* 2008). There is increasing pressure on natural resources like decline in watertable, nutrient imbalance, changing disease and pest scenario in the country, which had ultimately lead to decline in crop productivity and emerging agro-ecological problems. In this condition, maize-based cropping system is the solution to overcome this pressure owing to its exuberant ability to growth. These systems can ensure food and nutritional security by utilizing declining land and water resources. Both maize and potato are nutrient exhaustive crops and respond well to the higher levels of fertilizers. A crop of maize yielding about 14 tonnes/ha of dry matter takes up about 161, 34 and 110 kg/ha NPK respectively. Similarly, a good crop of potato yielding about 40 tonnes removes 170–180, 25 and 250 kg/ha NPK respectively (FAI, 2008). The application

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of heavy doses of chemical fertilizers enhanced the productivity of these crops on one end but at another end continuous application of chemical fertilizers deteriorates soil health, leading to declining productivity of the soil. The application of scientific approaches of organic farming is an alternative and holistic way for sustainable agriculture production that focuses on the soil health by largely excluding the use of chemicals and including organic manures. In addition, organic farming has potential to improve soil health indicators and content of essential micronutrients in grain produce; and conserving the natural resources. The prolonged effect of organic manures on soil fertility and soil moisture balance was also found (Kumar *et al*., 2005). Therefore the present study was planned to evaluate the effect of different levels of organic sources of nutrients on growth, yield and yield attributes of pop corn-potato cropping system.

MATERIALS AND METHODS

The field experiment was conducted during 2008–09 and 2009–10 at research farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi (28.40°N, 77.12°E and 228.6 m mean sea-level), having sub-tropical and semi-arid type climate with hot and dry summer, cold winter and mild to heavy rainfall. The mean annual rainfall of Delhi is 652 mm, of which 80% generally occurs during the monsoon season (July–September) with mean annual evaporation of 850 mm. Minimum and maximum temperature ranged between 11.0 and 35.0°C and 10.9 and 37.9°C, with the rainfall of 582.7 and 502.7 mm during growth period of pop corn in 2008 and 2009 respectively. Minimum and maximum temperature ranged between 1.4 and 31.5°C, and 1.4 and 33.0°C with total rainfall of 10.8 and 30.2 mm during the growth period of potato during 2008-09 and 2009-10, respectively. The soil was sandy loam with bulk density 1.54 and 1.52 Mg/m^3, organic carbon 0.38 and 0.40%, available N 159.4 and 162.2 kg/ha, phosphorus 14.6 and 15.2 kg/ha and potassium 165.7 and 169.5 kg/ha in first and second year respectively. The soil pH and electrical conductivity were 7.7 and 7.6; and 0.29 and 0.31 dS/m during 2008-09 and 2009-10, respectively. The experiment consisting of 24 treatment combinations was carried out in 3 times replicated factorial randomized block design. In pop corn, there was 8 treatments [control, recommended dose of fertilizers (RDF) ($N_{120}P_{25}K_{35}$ kg/ha), farmyard manure equivalent to120 kg N/ha (FYM_{120}), leaf compost equivalent to 120 kg N/ha (LC_{120}), vermicompost equivalent to 120 kg N/ha (VC_{120}), farmyard manure equivalent to 90 kg N/ha (FYM_{90}), leaf compost equivalent to 90 kg N/ha (LC_{90}) and vermicompost equivalent to 90 kg N/ha (VC_{90})]. In succeeding crop of potato, 3 treatments [control, farmyard manure equivalent to 60 kg N/ha (FYM_{60}) and farmyard manure equivalent to 90 kg N/ha (FYM_{90})] were superimposed on the different treatments of pop corn. The required quantity of different manures, viz. FYM, vermicompost and leaf compost as per the treatments was applied in field 10 days before sowing of both the crops. The available N, P and K content were 1.6, 0.50 and 1.52% in vermicompost, 0.48, 0.28, and 0.51% in FYM and 0.67, 0.29 and 0.27% in leaf compost respectively. The recommended dose of fertilizer (RDF) (N_{120} $P_{25}K_{35}$ kg/ha) in pop corn was applied through urea, single superphosphate and muriate of potash respectively. The nitrogen was applied into 3 splits ($^1/_3$ each as basal, tasseling and grain-formation stage). Full amounts of P and K were applied basal along with 25 kg/ha $ZnSO_4$. The seed of 'VL Amber Pop' was dibbled on the ridge sides at a spacing of 20 cm at 4 cm depth and required plant population (83,000 plants/ha) was maintained by thinning of plants 1 week after germination. Similarly, 'Kufri Badshah' potato seed tubers of 25–30 mm size were sown 5 cm deep on the south side of the ridges at a spacing of 20 cm between tubers. For studying the growth and yield attributes parameters of pop corn and potato five plants were tagged randomly in second row of either side in the field. Dry matter and leaf area were studied from 3 random plants from second row in pop corn and potato and the yield and yield attributes were record at harvest.

RESULTS AND DISCUSSION

Popcorn

Growth parameters: The tallest plants with maximum leaf-area index (LAI) and dry matter (DMA) were noticed with the application of RDF ($N_{120}P_{25}K_{35}$kg/ha) probably owing to faster availability of nutrients to plants through inorganic sources during the crop growth and development period (Table 1). Amongst the organic sources, application of vermicompost equivalent to 120 kg N/ha (VC_{120}) resulted in the highest plant height, LAI and dry matter, but these parameters were statistically at par that at VC_{90}, FYM_{120}, FYM_{90} and $N_{120}P_{25}K_{35}$ kg/ha levels. However, the respective increase in DM with RDF ($N_{120}P_{25}K_{35}$ kg/ha) was 28.1% over control. Further, it was revealed that DMA with application of vermicompost equivalent to 120 kg N/ha and FYM equivalent to 120 kg N/ha registered 27.5% and 24.5% increase over the control respectively. The vermicompost showed the superiority to the leaf compost at both the levels. Vermicompost and farmyard manure are rich source of macro-and micro-nutrients and growth hormones, which not only supply essential nutrients to the soil but also improve the physico-chemical and biological properties of the soil (Sharma *et al*., 2005;

Rawat and Pareek, 2003). The improved physico-chemical properties and slow release of nutrients over longer period with the uses of organic sources might be responsible for better growth of pop corn plants with FYM and vermicompost application. The improvement in plant height and LAI with the use of organic sources consequently enhanced the dry matter/plant. These results corroborate the findings of Jayaprakash *et al*. (2004) and Kumar *et al*. (2007). However, days to silking % and barren plants/ha could not be affected significantly by different levels and sources of nutrients.

Yield attributes: The application of RDF ($N_{120}P_{25}K_{35}$ kg/ha) recorded significantly maximum length and girth of cobs, grains/cob, cobs/ha and shelling (%) owing to better growth of plants in terms of leaf-area index and dry matter and more translocation of dry matter to productive parts of the crop (Table 2). Among the organic sources of nutrients, application of vermicompost equivalent to 120 kg N/ha resulted in the highest cob length and girth, grain/cobs cobs/ha, and shelling % but these yield-attributing characters were statistically at par with application of VC_{90}, FYM_{120}, FYM_{90} and $N_{120}P_{25}K_{35}$ kg/ha treatments. Higher LAI might have improved the values of yield attributes with application of vermicompost. However, compared to various sources and levels of nutrients application of leaf-compost equivalent to 90 or 120 kg N/ha recorded the lower values of yield attributes of pop corn but remained significantly higher over the control. Further, results revealed that 1,000-grain weight of pop corn and harvest index could not be differed significantly by the various nutrients management practices.

Yield: Significantly higher grain and stover yields of pop corn were recorded under various levels and sources of nutrients over the control (Table 2). The grain and stover yield of pop corn attained the highest values with the RDF ($N_{120}P_{25}K_{35}$ kg/ha). It might be owing to increased nutrients availability, which resulted in greater assimilation, production and partitioning of dry matter yield. Among different organic sources, application of vermicompost equivalent to 120 kg/ha resulted in signifi-

Table 1. Effect of varying levels and sources of nutrients on growth and yield attributes of pop corn (pooled data of 2 years)

Treatment	Plant height at maturity (cm)	Leaf-area index at 60 DAS	Dry-matter accumulation at maturity (g/plant)	Days to 50% silking	Barren plants ($\times 10^3$ /ha)	Cobs ($\times 10^3$/ha)
Control	125.0	2.79	89.8	63.8	10.2	57.5
$N_{120}P_{25}K_{35}$	157.8	3.95	115.1	58.4	8.3	73.5
FYM_{120}	154.8	3.81	111.8	59.3	8.6	71.7
LC_{120}	142.2	3.53	103.9	61.3	9.6	66.6
VC_{120}	157.1	3.89	114.5	58.3	8.2	73.2
FYM_{90}	149.8	3.51	109.4	60.1	9.5	69.4
LC_{90}	140.1	3.21	101.7	61.7	9.9	64.0
VC_{90}	154.2	3.51	111.2	58.6	8.5	70.9
SEm±	4.41	0.10	3.09	2.76	0.50	1.98
CD (P=0.05)	9.04	0.21	6.34	5.67	1.03	4.06

Details of treatments are given under material and methods; DAS, Days after sowing

Table 2. Effect of levels and sources of nutrients on yields attributes and yield of popcorn (pooled data of 2 years)

Treatment	Cob length (cm)	Cob girth (cm)	Grains/cob	1,000-grain weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Shelling (%)	Harvest index (%)
Control	10.7	8.4	278	127.8	1.96	3.85	62.9	33.4
$N_{120}P_{25}K_{35}$	14.2	10.5	346	149.7	2.97	5.16	78.1	36.5
FYM_{120}	13.3	10.1	340	146.7	2.87	4.94	76.0	36.6
LC_{120}	12.9	9.4	312	141.4	2.69	4.63	72.4	36.7
VC_{120}	14.0	10.2	343	149.0	2.95	5.07	77.3	35.9
FYM_{90}	12.8	9.7	329	143.8	2.78	4.85	74.1	36.8
LC_{90}	12.1	9.3	309	140.1	2.62	4.51	70.6	37.4
VC_{90}	13.3	10.1	338	145.2	2.86	4.94	75.0	36.8
SEm±	0.36	0.26	9.1	4.57	0.08	0.14	2.09	0.87
CD (P=0.05)	0.75	0.55	18.6	9.37	0.16	0.29	4.29	1.79

Details of treatments are given under materials and methods cantly highest grain and stover yields. However, these were statistically at par with that of VC_{90}, FYM_{120}, FYM_{90} and $N_{120}P_{25}K_{35}$ kg/ha levels. Further, results revealed that RDF ($N_{120}P_{25}K_{35}$ kg/ha) increased 51.5 and 34.2% grain and stover yield over the control respectively. While the application of vermicompost equivalent to 120 kg N/ha increased grain and stover yields by 50.5 and 31.7% over the control, respectively. The higher yield observed with the application of vermicompost in comparison to FYM may be explained on the basis of higher nutrient content, faster decomposition and released nutrients in vermicompost besides enhancing the microbial population and higher root biomass (Kannan *et al*., 2005). Further, FYM equivalent to 120 kg N/ha recorded 46.2 and 28.2% higher grain and stover yield over the control respectively. The considerable improvement in grain yield owing to application of organic sources might be attributed to the fact that organic sources of nutrients had the positive effect on yield attributes and cumulative effect of yield attributes mainly responsible for higher productivity with the application of organic sources. The results confirm those of Meena *et al.* (2007). Among the various levels and sources of nutrients the application of leaf compost at both levels (120 and 90 kg N/ha) had lower grain yield compared to other organic sources of nutrients and respective increased in grain yield was to the tune of 37.0 and 33.6 at 120 and 90 kg N/ha equivalent level as compared to the control respectively.

Potato

Growth parameters: Plant height, LAI, haulms/hill and dry matter (DM) in haulms differed significantly on residual fertility and with direct application of various levels and sources of nutrients (Table 3). On residual fertility of FYM equivalent to 120 kg N/ha, potato plant recorded the highest plant height, LAI, number of haulms and DM in haulms. The FYM (equivalent to 90 kg/ha) and vermicompost (equivalent to 120 kg N/ha) exhibited similar effect to FYM @ 120 kg N/ha. Further, the residual fertility of FYM equivalent to 120 kg N/ha increased dry matter of haulms by 35.3% over the control. This was because of higher residual availability of macro-and micronutrients under organic sources of nutrients, viz. FYM and vermicompost. Jamwal (2005) and Kumar (2008) reported similar positive residual effect of organic sources applied to previous crop on succeeding crop. In terms of growth parameters of potato, all the nutrient levels and sources of nutrients applied previous pop corn crop comprising organic sources is better substitution of chemical fertilizers regarding residual effects. Application of organic sources of nutrients to potato improved its growth parameters significantly over the control (Table 3). Application of FYM equivalent to 90 kg N/ha recorded the highest plant height, LAI, haulms/hill and DM in haulms as compared to the control and FYM (equivalent to 60 kg N/ha). The FYM equivalent to 60 kg N/ha also recorded higher growth parameters than the control. It might be because of improv-

Table 3. Direct and residual effects of varying levels and sources of nutrients on growth, yields and yield attributes of potato (pooled data of 2 years)

Treatment	Plant height at maturity	Leaf area index at 90 DAS	Haulms/hill at maturity	Dry matter accumulation at maturity (g/hill)	Number of tubers/hill	Fresh tuber weight (g/hill)	Dry tuber weight (g/hill)	Tuber (t/ha)	Haulm (t/ha)
To pop corn									
Control	34.2	2.69	4.10	16.6	6.7	284.1	38.3	15.2	1.39
$N_{120}P_{25}K_{35}$	37.5	2.90	4.72	19.0	7.8	315.7	43.6	17.3	1.62
FYM_{120}	45.7	3.48	5.62	22.5	9.1	382.4	57.5	22.3	1.99
LC_{120}kg	42.2	3.23	5.24	21.2	8.4	356.0	52.6	20.5	1.83
VC_{120}	44.6	3.42	5.58	22.4	9.0	380.5	56.2	22.0	1.97
FYM_{90}	44.1	3.38	5.35	21.6	8.7	369.1	55.0	21.5	1.93
LC_{90}kg	39.8	3.03	4.87	19.9	7.8	332.5	48.9	19.1	1.70
VC_{90}kg	43.6	3.34	5.31	21.4	8.6	364.2	53.9	20.9	1.91
SEm±	0.57	0.05	0.07	0.3	0.13	5.5	0.9	0.2	0.03
CD (P=0.05)	1.63	0.14	0.21	0.9	0.37	15.6	2.4	0.7	0.07
To potato									
Control	35.0	2.74	4.18	16.7	6.7	292.5	38.6	15.5	1.39
FYM_{60}	43.4	3.31	5.33	21.8	8.7	366.8	54.7	21.5	1.91
FYM_{90}	45.9	3.50	5.78	23.2	9.5	384.8	58.9	22.6	2.08
SEm±	0.35	0.03	0.05	0.2	0.08	3.4	0.5	0.2	0.02
CD (P=0.05)	1.00	0.09	0.13	0.6	0.23	9.5	1.5	0.4	0.05

Details of treatments are given under materials and methods

Table 4. Interaction effects of fertility levels applied to popcorn and potato on dry matter of haulms, dry weight of tuber and tuber yield of potato (pooled data of 2 years)

Treatment to popcorn	Treatment to potato								
	Dry matter in haulms (g/hill)			Dry weight of tubers (g/hill)			Tuber yield (t/ha)		
	Control	FYM_{60}	FYM_{90}	Control	FYM_{60}	FYM_{90}	Control	FYM_{60}	FYM_{90}
Control	13.6	17.2	19.1	21.4	40.8	52.6	12.5	14.9	18.2
$N_{120}P_{25}K_{35}$	16.4	18.0	22.8	37.2	45.6	47.9	14.8	18.0	19.2
FYM_{120}	17.2	23.4	26.8	42.3	60.2	70.0	16.6	24.8	25.5
LC_{120}	17.0	22.9	23.6	39.8	56.9	61.0	15.1	23.1	23.3
VC_{120}	17.7	24.7	24.8	42.2	61.2	65.3	16.6	24.2	25.2
FYM_{90}	17.3	22.5	24.9	42.7	58.7	63.5	16.3	23.0	25.1
LC_{90}	16.2	22.5	20.9	36.9	53.8	56.1	14.6	21.4	21.4
VC_{90}	18.0	23.6	22.6	46.4	60.7	54.4	17.3	22.8	22.7
SEm±		0.5			1.5			0.43	
CD (P=0.05)		1.6			4.2			1.22	

Details of treatments are given under materials and methods

ing soil structure, enhanced water holding capacity, soil microbial activity and available soil nutrients like NPKS to plants with the application of FYM (Ayyub *et al*., 2011).

Yield attributes: Tubers/hill, fresh and dry weight of potato tubers were significantly affected by the residual and direct application of various levels and sources of nutrients (Table 3). The highest values of yield attributes of potato were recorded on the residual fertility of FYM (equivalent of 120 kg N/ha), being statistically at par with the residual fertility of VC_{120}, LC_{120}, FYM_{90} VC_{90} and LC_{90}. The maximum number of tubers/hill, fresh tuber weight and dry tuber weight were with residual fertility of FYM equivalent to 120 kg N/ha could be owing to more availability of macro-and micro-nutrients nutrients. However, lower values of yield attributes were noticed on the residual fertility of leaf compost. Dry weight of potato tubers with FYM_{120} increased by 50.3 and 31.9% over the control and residual fertility of RDF ($N_{120}P_{25}K_{35}$ kg/ha), which was apply to preceding pop corn crop. Application of FYM equivalent to 90 kg N/ha to potato recorded significantly higher yield attributes, viz. tubers/hill, fresh tuber weight and dry tuber weight than 60 kg N/ha as FYM and the control. Similarly, FYM equivalent to 60 kg N/ha also reported significantly higher yield attributes compared to the control. The interaction effect of treatment applied to popcorn and potato on dry matter of potato haulms and tubers were also found significant (Table 4). The maximum dry matter weight of haulms and tubers/hill was recorded, when FYM equivalent to 120 kg N/ha in pop corn and 90 kg N/ha in potato was applied. However, it remained at par with the treatment combination of FYM in potato with either FYM (equivalent to120 kg N/ha)/vermicompost (equivalent to120 kg N/ha) or FYM (equivalent to 90 kg N/ha) in pop corn; and FYM (equivalent to 90 kg N/ha) in potato. The higher yield attributes of potato with the use of FYM may be explained on the basis of higher nutrient availability to plants and improved physical and microbial activity with FYM application (Das *et al*., 2002).

Yield: The potato tuber and haulms yield were significantly differed with residual fertility and direct application of varying sources and levels of nutrients (Table 3). The highest tuber and haulm yields were recorded on the residual fertility of FYM application @ 120 kg N/ha which remained at par with that on residual fertility of VC_{120}, LC_{120}, FYM_{90} VC_{90} and LC_{90}. In general, tuber yield with FYM equivalent to 120 kg N/ha was 47.1 and 28.9% higher over the control and RDF ($N_{120}P_{25}K_{35}$ kg/ha). Further, all the organic sources of nutrients resulted in higher tuber and haulm yields compared to RDF. Among the different residual fertility levels, leaf compost (LC) at both levels (90, 120 kg N/ha) recorded the lower values of tuber and haulms yield than FYM and vermicompost. Application of FYM equivalent to 90 kg N/ha recorded significantly higher tuber and haulms yields than FYM equivalent 60 kg N/ha and the control. In general, increase in tuber yield with application of the FYM (90 kg N/ha) was 46.0 and 4.9% over the control and FYM equivalent to 60 kg N/ha. It might be due to more supply of macro-and micro-nutrients and better soil physical health for development of tuber with application of FYM (Zaman *et al*., 2011). Significant variation in tuber yield of potato due to interaction effect of fertility levels to popcorn and potato were noticed (Table 4). The maximum tuber yield of potato were noticed, when FYM was applied equivalent to 120 kg N/ha in popcorn and 90 kg N/ha in potato. However, the treatment combinations of FYM (equivalent to 60 kg N/ha) in potato with either FYM (equivalent to120 kg N/ha) or vermicompost (equivalent to120 kg N/ha) or FYM (equivalent to 90 kg N/ha) in popcorn; and FYM (equivalent to 90 kg N/ha) in potato with vermicompost (equivalent to 120 kg N/ha) or FYM (equivalent to 90 kg N/ha) in popcorn remained statistically equal to the best performing treatment combination (FYM_{120} in pop corn × FYM_{90} in potato), which gave the highest yield.

It was concluded that application of FYM equivalent to 120 kg N/ha in popcorn and 90 kg N/ha in potato was the most productive combination, but application of 120 kg N/ha by either FYM or vermicopmost in pop corn followed by 60 kg N/ha by FYM in potato is also a good combination in pop corn-potato sequence.

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