



Cropping geometry and nutrient management study on winter maize (*Zea mays*) + potato (*Solanum tuberosum*) intercropping

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ABSTRACT

Field experiment was conducted during *rabi* during 2015-16 and 2016-17 at Varanasi (UP) to study the effect of cropping geometry and nutrient management on winter maize (*Zea mays* L.) + potato (*Solanum tuberosum* L.) intercropping. Among the crop geometry, winter maize intercropped with potato (1:1) in replacement series showed significantly higher growth parameters of maize, viz. dry matter accumulation, crop growth rate and number of green leaves per plant as compared to additive series but it was found at par when winter maize grown with potato (1:2) in replacement series. However, growth parameters of potato differed interchangeably as compared to maize in winter maize + potato intercropping system during both the years. Significantly higher grain yield of winter maize and potato were found in intercropping with 1:1 and 1:2 in additive series, respectively. Assessment of intercropping indices and economics of maize and potato proved to be better in additive series as compared to replacement series during both the years of experimentation. Amongst nutrient management, growth parameters, yield attributes and yield, intercropping indices and economics of winter maize + potato were recorded significantly higher with the application of 100% RDF + 25% N through poultry manure followed by the application of 100% RDF + 25% N through vermicompost as compared to rest of the treatments during both the years. Thus, it may be concluded that the maize + potato intercropping in additive series with integration of poultry manure as N source gives better yield and economics of both the crops.

Keywords: Equivalent yield, Intercropping, Land equivalent ratio, Potato, Winter maize

One way to improve the land use efficiency (LUE) is through intercropping of companion crops including winter maize (*Zea mays* L.) and potato (*Solanum tuberosum* L.). Because of being a slow growing (especially during winters) and wide row crop, winter maize provide sufficient time and space in the field to incorporate short duration intercrops. Potato, because of similar cultural requirements (especially earthing up and furrow irrigation) fits best as intercrop in winter maize. At the same time rational crop community structure plays an important role in maximizing the intercropping yield advantage. The proportion of component crops in intercropping is a vital factor for reducing the risk to the component crop during adverse weather conditions. Therefore, optimization of plant population (row ratio) of component crops is one of the thrust areas of research in intercropping systems to maximize returns per unit area.

Continuous use of only chemical fertilizers in intensive cropping system is leading to imbalance of nutrients in soil, which has an adverse effect on soil health and also on crop yields. But use of organics alone does not result in spectacular increase in crop yields due to their low nutrient content and slow availability (Kumar *et al.* 2016). Complementary use of biological sources of plant 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. In which, integrated nutrient management entails the maintenance/adjustment of soil fertility to an optimum level for enhancing the crop productivity to get the maximum benefit from all possible combination sources of nutrients – organic as well as inorganic – in an integrated manner (Shukla *et al.* 2013). Keeping all these facts in view, an experiment was conducted to investigate the effect of crop geometry and nutrient management on winter maize + potato intercropping under irrigated conditions.

MATERIALS AND METHODS

Field experiment was conducted during the winter (*rabi*) season of 2015–2016 and 2016–17 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (UP). Geographically,

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experimental site falls under sub-tropical zone of Indo-Gangetic plains. It is located on 25°15'19.7"N latitude, 82°59'34.2"E longitude and at an altitude of 76 m above mean sea level. The experimental soil was sandy clay loam, neutral in reaction (pH 7.45), EC (0.18) dS/m organic carbon (0.36%), bulk density (1.37 g/cc), particle density (2.61 g/cc), medium in available N (199.89 kg/ha), P (20.28 kg/ha) and K (205.66 kg/ha). The field experiment was carried out in split-plot design with 3 replications. The main plot treatments consisted of 4 crop geometries of maize + potato intercropping, viz. maize + potato (1:1) at 60 cm × 20 cm in replacement series, maize + potato (1:2) at 60 cm × 20 cm in replacement series, maize + potato (1:1) at 75×20 cm in additive series and maize + potato (1:2) at 75 cm × 20 cm in additive series. The sub plot treatments consisted of 5 nutrient management practices, viz. 100% RDF, 100% RDF + 25% N through vermicompost, 100% RDF + 25% N through poultry manure, 75% RDF + 25% N through vermicompost + *Azotobacter* and 75% RDF + 25% N through poultry manure + *Azotobacter*. In intercropping system, the maize was taken as main crop and potato as component crop. Apart from these treatment plots, two plots, one each for sole maize crop and sole potato crop were maintained with recommended package and practice. The yield from these sole crop plants was used only for the calculation of intercropping indices. The recommended dose of fertilizer for maize and potato crop was 150, 80, 80, and 120, 60, 120 kg N, P₂O₅ and K₂O/ha, respectively. Half dose of N, full dose of P and K were applied as basal application at the time of sowing/planting of maize and potato crops and remaining half dose of N were applied as top dressing at the knee high stage of winter maize and at the time of earthing up in potato. Bulky organic manure (vermicompost and poultry manure) were also applied as basal application within the row at the time of sowing/planting of maize and potato over the plot as per the treatment. The late maturing variety of maize hybrid DKC-9081 and medium maturing variety of potato Kufri Badshah were taken for conducting a field experiment during both the years. Seed/tuber of maize and potato were sown in second fortnight of November. *Azotobacter* was used to inoculate the maize seeds and potato tubers as per the treatment. For maize, slurry was prepared by boiling 100 g jaggery in one litre of water. After cooling, 200 g bio-fertilizer was dissolved in the jaggery mixture for seed treatment. The mixture was optimum for treatment of 10 kg of maize seed. *Azotobacter chroococcum* culture solution was prepared by mixing 50 g bacterial culture and 100 g jaggery in one litre of water. The solution was sprayed over 25 kg well sprouted tubers of potato. The tubers were planted in the field after drying in shade.

The land equivalent ratio (LER) was computed as per the formula proposed by Mead and Willey (1980). The land equivalent coefficient (LEC) and aggressivity were calculated using formula given by Adetiloye *et al.* (1983) and Mc-Gilchrist (1965), respectively. All the data generated in the experiment was analysed following standard statistical

procedure (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Yield attributes and yield: Maize intercropped with potato (1:1) in replacement series (60 cm × 20 cm) gave significantly higher number of grains per cob (425.01), which was statistically at par to maize intercropped with potato (1:2) in replacement series over rest of the treatments during both the years. Higher number of grains per cob under wider spacing was also reported by Khafi *et al.* (2000). Grain yield (56.86 q/ha) was found significantly higher under maize intercropped with potato (1:1) in additive series (75×20 cm) as compared to other crop geometry. Similar results and views were also reported by Mishra (2014). In case of nutrient management, number of grains (422.73 grains per cob) and grain yield (48.26 q/ha) were recorded significantly higher with the application of 100% RDF + 25% N through poultry manure, which was at par with the application of 100% RDF + 25% N through vermicompost during both the years. The increase in grain yield of maize was due to effective utilization of applied nutrient which increased the sink capacity of crop. Similar results were also found by Thavaprakash *et al.* (2005) (Table 1).

Various cropping geometries had significant influence on number of tubers per plant in potato. Significantly higher number of tubers per plant was noticed under maize + potato intercropping (1:2) in replacement series (60 cm × 20 cm), which was statistically at par with maize + potato (1:1) in replacement series as compared to other crop geometry during both the years. Tuber yield (209.78 q/ha) was found significantly higher under maize intercropped with potato (1:2) in additive series as compared to other crop geometry during both the years. The lower yield under intercropping was due to less covered area and competition with maize as compared with sole crop. Reduction of intercrops yield in different situation was also observed by Singh (2000). Under nutrient management, the application of 100% RDF + 25% N through poultry manure produced highest number of tubers/plant and highest tuber yield (152.74 q/ha) which was significantly superior to all the treatments except 100% RDF + 25% N through vermicompost during both years. It appears that potato intercropped with maize at wider spacing could intercept more solar radiation and utilize it more efficiently thereby improving its all the yield attributing characters. These results are in close conformity to those reported by Porwal *et al.* (2006) and Verma *et al.* (2018). Integration of organic and inorganic inputs sustained the crop production due to positive interaction and complementarities between them, these findings are in close conformity with the findings of Taye (2011) who noted the significant increase in tuber yield components with increasing organic manure and inorganic fertilizers which might be due to higher nutrient availability and uptake with the higher rates of both fertilizer types and increased availability of plant nutrients (Kundu 2007). The result clearly revealed that the total yield and marketable yield

Table 1 Effect of crop geometry and nutrient management on yield attributes and yields of maize + potato intercropping system (mean data of two years)

Treatment	Number of grains/cob	Grain yield (q/ha)	Number of tubers/plant	Tuber yield (q/ha)	Maize grain equivalent yield (q/ha)
	Maize		Potato		
<i>Main plot : Crop geometry</i>					
1:1 (M+P) 60 cm × 20 cm *	425.01	41.72	8.36	105.65	105.18
1:2 (M+P) 60 cm × 20 cm *	413.18	29.44	8.56	136.42	111.45
1:1 (M+P) 75 cm × 20 cm **	389.47	56.86	7.19	129.14	134.44
1:2 (M+P) 75 cm × 20 cm **	379.68	51.46	6.51	209.78	177.48
SEm ±	3.90	0.72	0.06	0.61	0.55
CD (P=0.05)	13.48	2.49	0.22	2.10	1.91
<i>Sub plot : Nutrient management</i>					
100% RDF	403.79	41.46	7.77	137.37	123.98
100% RDF + 25% N through vermicompost	414.76	46.74	8.06	148.99	136.24
100% RDF + 25% N through poultry manure	422.73	48.26	8.19	152.74	140.02
75% RDF + 25% N through vermicompost + <i>Azotobacter</i>	378.13	43.21	6.76	142.47	128.85
75% RDF + 25% N through poultry manure + <i>Azotobacter</i>	389.75	44.69	7.49	144.66	131.59
SEm ±	3.38	0.57	0.06	0.42	0.50
CD (P=0.05)	9.72	1.64	0.18	1.22	1.44
<i>Sole (mean)</i>					
Maize (60 cm × 20 cm)	432.88	62.61	-	-	-
Potato (60 cm × 20 cm)	-	-	8.81	245.65	-

*Replacement series and **Additive series, MSP of maize was ₹ 1365/q and local market price of potato was ₹ 820/q.

of potato could be increased by the interaction of organic and inorganic fertilizer.

Maize grain equivalent yield (MGEY)

Maize intercropped with potato (1:2) in additive series (75 × 20) showed the best performance for maize grain equivalent yield as compared to other crop geometry and sole crops. This increase was mainly due to additional yield advantage of potato during both the years. Tripathi *et al.* (2010) also reported that winter maize intercropped with potato recorded significantly higher maize equivalent yield than the sole crop. The highest maize grain equivalent yield of 140.02 q/ha was recorded when maize received 100% RDF + 25% N through poultry manure and the second best was 100% RDF + 25% N through vermicompost during both the years (Table 1). Maize grain equivalent yield was higher due to the addition of organic manure with inorganic fertilizers. These results are in accordance with findings of Thavaprakash *et al.* (2005).

Aggressivity: Maize with positive aggressivity factor was aggressive under both the crop geometries in intercropping and amongst nutrient management acted as a dominant crop component but potato with negative aggressivity factor was aggressive under all crop geometries as well as nutrient

management in intercropping acted as a dominated crop. Aggressivity values were greater than zero in both crop geometries and nutrient management in intercropping system, indicating yield advantage over sole maize (Table 2). These results were also in accordance with the same finding by Chhetri and Sinha (2018).

Land equivalent coefficient: Maize intercropped with potato (1:2) in additive series (75 cm × 25 cm) showed the highest values of land equivalent coefficient (LEC) as compared to other crop geometry during both the years. Under different nutrient management, there was found the highest values with the application of 100% RDF + 25% N through poultry manure followed by the application of 100% RDF + 25% N through vermicompost as compared to other treatments during both the years (Table 2).

Land equivalent ratio: The highest Land equivalent ratio (LER) values were observed when maize intercropped with potato (1:2) in additives series (75 cm × 25 cm) as compared to other crop geometry during both the years. Amongst nutrient management, there was found the highest value with the application of 100% RDF + 25% N through poultry manure followed by the application of 100% RDF + 25% N through vermicompost, however the minimum Land equivalent ratio (LER) was revealed with the application

Table 2 Effect of crop geometry and nutrient management on biological feasibility (mean basis) and economical parameters of maize + potato intercropping system (mean data of 2 years)

Treatment	Aggressivity		Land equivalent coefficient	Land equivalent ratio	Net returns (× 10 ³ ₹/ha)	Benefit : cost
	Maize	potato				
<i>Main plot : Crop geometry</i>						
1:1 (M+P) 60 cm × 20 cm *			0.288	1.097	93.81	1.36
1:2 (M+P) 60 cm × 20 cm *			0.262	1.026	98.24	1.37
1:1 (M+P) 75 cm × 20 cm **	0.77	-0.77	0.479	1.434	126.64	1.53
1:2 (M+P) 75 cm × 20 cm **	1.19	-1.19	0.703	1.676	159.84	1.41
SEm ±			0.004	0.010	0.83	0.010
CD (P=0.05)			0.015	0.034	2.85	0.040
<i>Sub plot : Nutrient management</i>						
100% RDF	0.45	-0.45	0.379	1.221	115.93	1.50
100% RDF + 25% N through vermicompost	0.52	-0.52	0.462	1.353	113.94	1.18
100% RDF + 25% N through poultry manure	0.54	-0.54	0.487	1.392	133.27	1.60
75% RDF + 25% N through vermicompost + <i>Azotobacter</i>	0.46	-0.46	0.407	1.271	110.21	1.23
75% RDF + 25% N through poultry manure + <i>Azotobacter</i>	0.48	-0.48	0.429	1.303	124.81	1.57
SEm ±			0.004	0.007	0.73	0.01
CD (P=0.05)			0.012	0.019	2.11	0.03
<i>Sole (mean)</i>						
Maize (60 cm × 20 cm)					55.58	1.14
Potato (60 cm × 20 cm)					136.06	1.68

*Replacement series and **Additive series

of 100% RDF during both the years of experimentation. Similar results were also found by Dua *et al.* (2005).

Economics: Significantly highest net return (₹ 159840/ha) was found when maize intercropped with potato (1:2) in additive series (75 cm $\times$ 20 cm). However, benefit: cost ratio (1.53) was found maximum when maize intercropped with potato (1:1) within same intercropping system as compared to other crop geometry. The lowest net returns and benefit: cost ratio was found when maize intercropped with potato (1:1) in replacement series (60 $\times$ 20) during both the years of experiment. Kour *et al.* (2014) were also reported that maize-based intercropping system recorded significantly higher net returns and benefit: cost ratio as compared to sole winter maize. Higher net profit was gained in winter maize + potato (additives series). These results were also accordance with the finding of Shivay *et al.* (2001) and Padhi and Panigrahi (2006) that net returns from the intercropping treatments were more than sole crops. Among the nutrient management, the highest net returns and benefit: cost ratio were obtained with the application of 100% RDF + 25% N through poultry manure as compared to other nutrient management. The lowest net returns and benefit : cost ratio was found with the application of 100% RDF during both the years (Table 2). Similar results were also reported by Yogesh *et al.* (2014).

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